AD-A013 995

FRANGIBILITY TESTS OF EXISTING APPROACH LAMPS AND HOLDERS

Bret B. Castle

National Aviation Facilities Experimental Center

Prepared for:

Federal Aviation Administration

August 1975

Report No. FAA-RD-75-97

247084

ADA013995

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INTERIM REPORT

Document is available to the public through the National Technical Information Service, Springfield, Virginia 22151

Prepared for

U. S. DEPARTMENT OF TRANSPORTATION

FEDERAL AVIATION ADMINISTRATION

Systems Research & Development Service

Washington, D. C. 20590

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Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FAA-RD-75-97		

4. Title and Subtitle	5. Report Date
FRANGIBILITY TESTS OF EXISTING APPROACH LAMPS AND HOLDERS	August 1975
	6. Performing Organization Code
7. Author(s): Bret B. Castle	8. Performing Organization Report No.: FAA-NA-75-8
9. Performing Organization Name and Address: Federal Aviation Administration, National Aviation Facilities Experimental Center, Atlantic City, N.J. 08405	10. Work Unit No. (TRAIS)
	11. Contract or Grant No.: 072-324-000
12. Sponsoring Agency Name and Address: U.S. Department of Transportation, Federal Aviation Administration, Systems Research and Development Center, Washington, D.C. 20590	13. Type of Report and Period Covered: Interim, July - December 1974
	14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

Tests were conducted on approach lamps and holders to determine to what extent current designs are frangible. A catapult accelerated the fuselages of two widely used types of small aircraft to collision with PAR-38 and PAR-56 lamps and associated holders. A total of 53 runs at different speeds and with different exposed lamp face orientations resulted in evidence that most small, general aviation aircraft windshields will shatter with lamp penetration at less than flying speeds. Results show that a safety redesign of the lamps might reduce penetration probability and result in a lamp that will not penetrate windshields at less than approach landing speeds.

17. Key Words	18. Distribution Statement
Lamps Approach Light Windshield Frangible	Document is available to the public through the National Technical Information Service, Springfield, Virginia 22151 PRICES SUBJECT TO CHANGE

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	44	3.75-2.25

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PREFACE

The author would like to thank the NAFEC Structures Branch including the Catapult and Track Facility and the photographic teams for their excellent help during this activity. Without their valuable assistance in the field tests, this work could never have been completed.

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INTRODUCTION

PURPOSE.

Tests were conducted with PAR-38 and PAR-56 lamps and holders to determine the frangibility of the approach lighting system (ALS) lamps and holders when struck by general aviation aircraft. Data was obtained in order to answer the following questions:

1. What is the relative safety of existing aircraft windshields when impacted by ALS lamps and holders at approach speeds?

2. What are the impact parameters for a "safe" ALS light assembly?

3. What are the impact characteristics of the windshields when struck by just the PAR-38 or PAR-56 lamps?

4. Can a PAR-38 or PAR-56 lamp be utilized, or will a new lamp technique be necessary?

BACKGROUND.

One of the hazards encountered when flying into a major airport today is the possibility of accidentally undershooting the threshold of the runway and impacting into present-day approach lighting systems located there. These approach lights consist of glass and steel bars that are very rigid. Up-to-date frangible structures are being tested and are, in some cases, being used at airports for crash safety considerations. It follows that the lamps and holders themselves must also be made frangible. Toward this end, it is desirable to ascertain the impact characteristics of the lamps and holders.

DISCUSSION

TEST PROCEDURES.

The NAFEC catapult system was utilized to accelerate the fuselages of Cherokee 180 and Cessna 172 airplanes, with the windshields of each impacting into PAR-38 and PAR-56 lamps and holders. Different speeds were used to determine the impact characteristics of the involved items and to obtain statistics for future comparison.

The lamps and lamps with holders were hung in the air with as little support as possible and were struck by the windshields at their in-flight attitude (tilted about 30° from horizontal). Speeds started at 20 miles per hour (mi/h) and were increased until windshield penetration thresholds were obtained. Instrumentation consisted of photographic evidence and accelerometer data.

The tests were run in the following order:

1. Piper Cherokee 180 windshields were impacted against the following lamps with the lamp faces toward the windshields:

   a. PAR-56 lamps alone,
   b. PAR-56 lamps and holders,
   c. PAR-38 lamps alone,
   d. PAR-38 lamps and holders, and
   e. PAR-38 lamps and holders with accelerometers attached.

2. Cessna 172 windshields were impacted against the same lamps and holders as in 1 above.

3. In addition, Piper Cherokee 180 windshields were impacted against:

   a. PAR-38 lamps and holders with the lamp faces striking flat against the windshields, and

   b. PAR-38 lamps and holders with the sharp edges of holders facing toward the windshields.

Photographs of the impact tests were taken from inside the fuselage with a 16-millimeter (mm) Photo-Sonics Incorporated model 1-B camera running at 500 frames per second. High-speed documentation was obtained by use of a 16-mm Hy Cam model K1001 camera, running at 3,500 frames per second. Still photographs were also taken, and certain photographs are included in this report.

EQUIPMENT DESCRIPTION.

WINDSHIELDS. The windshields of both the Piper and Cessna aircraft are made from a general-grade acrylic resin (Lucite® and Plexiglas G® are examples). Windshields are generally purchased to specifications MIL-P-21105 or L-P-391, which specify a thickness of 0.125 inches, with tolerances of +0.020 inches and -0.030 inches for the windshield sizes used on the test aircraft. The acrylic resin resists most weather conditions and is light, easily cut and shaped, dimensionally stable, and has great transparency.

LAMPS AND HOLDERS. The lamps and holders are the presently used lamps and holders of airport approach lighting systems. As there is a tendency toward use of lighter and less complex approach lighting systems, the majority of testing was with the lighter PAR-38 lamp and holder.

Weights and specifications of the lamps and holders are:

PAR-38 lamp = 9 ounces (255 grams)--specification L-848 (see Advisory Circular 150/5340-14B entitled "Economy Approach Lighting Aids," dated June 1970).

PAR-38 holder = 5 ounces (142 grams)--specification FAA-E-2325 entitled "Medium Intensity Approach Lighting System," dated 5-12-71.

PAR-56 lamp = 1 pound and 4 ounces (567 grams)--specification FAA-E-2408 entitled "Lamps, PAR-56, Incandescent Aviation Service," dated 5-4-70.

PAR-56 holder = 2 pounds and 15 ounces (1,332 grams)--specification FAA-E-982D, entitled "PAR-56 lampholder," dated 4-10-68.

ACCELEROMETERS. The accelerometers used during the tests were the Bell & Howell type 4-203-001, rated at $\pm$100 g with a weight of 4 ounces including the cable and connector. A Bell & Howell model 5-124 oscillograph was also used with a type 7-346 galvanometer, which has a flat response out to 190 hertz (Hz).

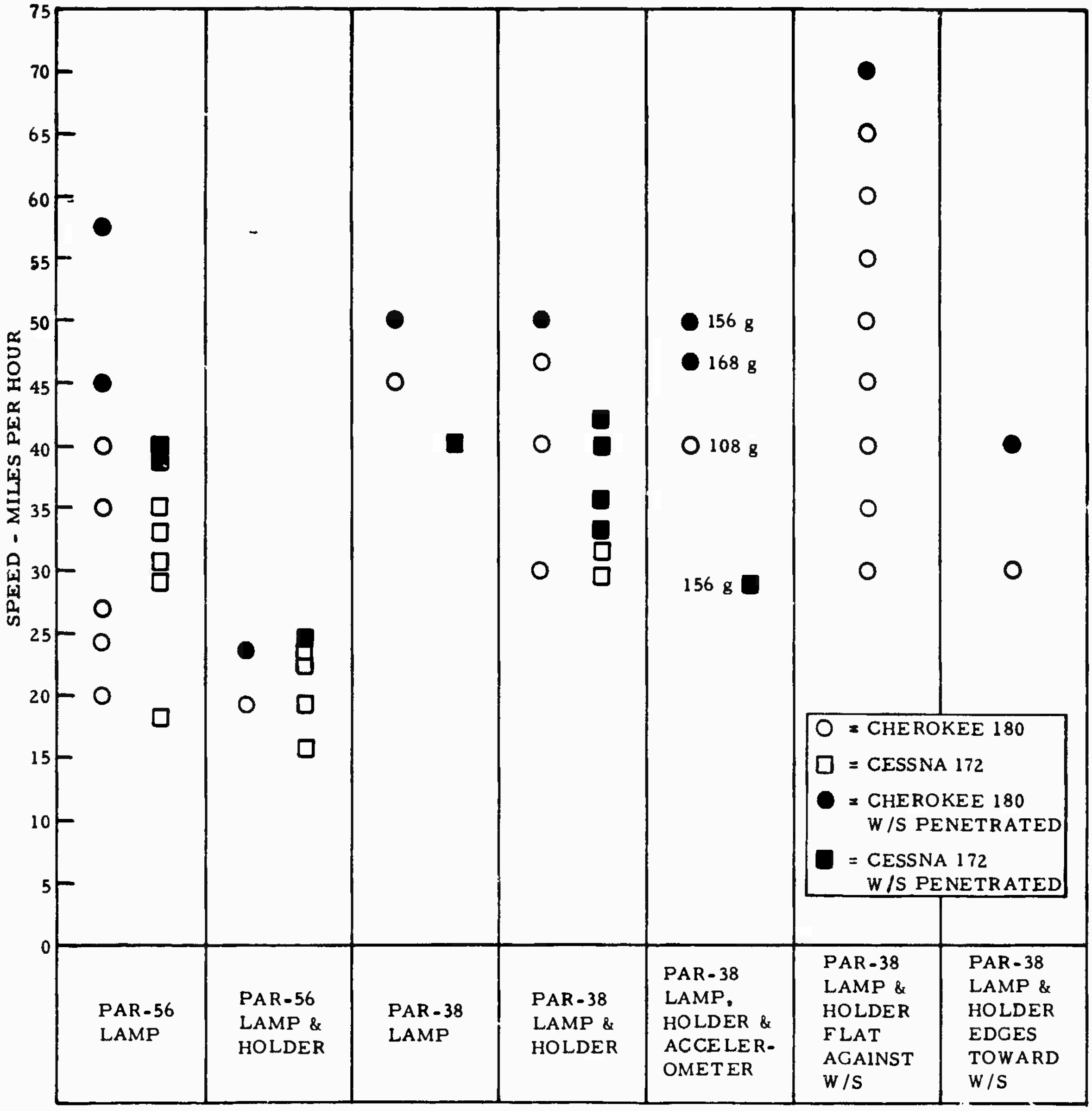
CATAPULT. The catapult and track facility is a fixed installation comprised of a launching catapult, a 300-foot track, and an operations building. The catapult is comprised of a compressed-air firing mechanism and a launcher car. The launcher car drives a pusher car on the 300-foot track, which in turn pushes a free-running car on which was mounted the fuselage of either the Piper Cherokee 180 or the Cessna 172. A Westinghouse brake, two Mark IV arresting engines, and two walk-back brakes comprise the arresting mechanism for the system. Speeds obtainable by this system are from near zero to 80 mi/h. The overall weight of the sled and fuselage is 1,750 pounds. A more complete description of the catapult test system can be found in FAA Manual, "Technical Facilities at NAFEC", RD P 6000.2, dated July 1, 1969.

TEST RESULTS

CATAPULT TESTS.

In order to make meaningful comparisons, data was collated into sets. The first set of runs (designated ALS runs) was made with the Cherokee 180 fuselage, which has two half windshields with a supporting metal strip down the middle. A second set of runs, duplicating the first set, used a Cessna 172 fuselage and windshield. The Cherokee 180 half windshield was about one-half the size of the larger Cessna 172 single windshield. An attempt was made to keep the impact point near the center of the Cherokee's half windshield (14 inches from the bottom and 10 inches from the center edge), as well as near the center of the Cessna 172 windshield. A summary of the run sets is listed with approximate speeds in table 1, and a complete set of data and remarks made at the time of the runs is enclosed in the appendix.

TABLE 1. LAMP CONFIGURATIONS VERSUS IMPACT SPEED



SET No. 1a. Seven runs (ALS-1 through 7) were made with the Cherokee windshield striking the face of a PAR-56 lamp. Figures 1, 2, 3, and 4 depict the test setup, nonpenetration and penetration runs, and the effect of a penetration run. The results show that the lamps are much less frangible than the windshields. The outcome of the impact tests at 20, 24, 36, 40, 47, and 58 mi/h shows that the lamps actually shattered the windshields at 47 and 58 mi/h.

SET No. 1b. Seven runs (ALS-26 through 32) were made with the Cessna 172 windshield striking the PAR-56 lamp held facing the windshield as in set No. 1a (figures 5 and 6). Impact speeds of 18, 29, 30, 33, 36, 38, and 40 mi/h were run, with windshields breaking at the 38 and 40 mi/h runs. This shows that the Cessna 172 windshields break at a speed about 9 mi/h slower than the break speed of the small Cherokee 180 windshield.

SET No. 2a. A second set of runs (ALS-8 and 9) using the Cherokee 180 fuselage and a PAR-56 lamp mounted in its normal holder was then made at 19 and 24 mi/h. The windshield was penetrated at 24 mi/h, as might be expected when impacting the heavy lampholder (figures 7 and 8).

SET No. 2b. This set of runs was similar to set No. 2a, except that five runs (ALS-33 through 37) were run with the Cessna 172 (figure 9). Speeds of 17, 19, 22, 23, and 24 mi/h were run with the windshields breaking at 24 mi/h. This speed is about the same as with the Cherokee windshield. This is in contrast to all of the other sets of runs, however, which show that the Cessna 172 windshields were penetrated at an impact speed of 9 mi/h slower than the Cherokee windshields.

SET No. 3a. Another set of runs (ALS-13 and 14) using the Cherokee 180 windshield and the PAR-38 lamp without holder was performed at 45 and 51 mi/h. The windshield was penetrated at 51 mi/h (figure 10).

SET No. 3b. With the Cessna 172 windshield and PAR-38 lamp as in set No. 3a, one run (ALS-38) penetrated the windshield at 40 mi/h (figure 11). This was 11 mi/h slower than the Cherokee 180 windshield.

SET No. 4a. A fourth set of six runs (ALS-10, 11, 12, 15, 16, and 17) was carried out using the Cherokee 180 and the PAR-38 lamp and holder facing the windshield. Speeds were at 31, 41, and 47 mi/h, plus three at 50 mi/h. The first three runs were at 31, 41, and 50 mi/h, with the windshield first being penetrated at 50 mi/h. A slower speed run of 47 mi/h was then conducted to confirm our results, and the windshield was not penetrated. Two more runs were made at 51 mi/h, both of which penetrated windshields. This gave a good indication that 50 mi/h will usually penetrate the windshields under these conditions (figure 12).

SET No. 4b. Six runs (ALS-22 through 25, 39, and 40) were made with the Cessna 172 windshield and PAR-38 lamps and holders as in set No. 4a. Run ALS-22 did not break the windshield at 32 mi/h. ALS-23, at 42 mi/h, did break the windshield, after which two more runs (ALS-24 and 25) at reduced speeds (36 and 33 mi/h) also broke the windshields. Next, ALS-39, at 29 mi/h, did not penetrate the windshield. Lastly, ALS-40 broke the windshield at 40 mi/h. This shows that 33 mi/h is the approximate threshold penetration speed for Cessna 172 windshields under these conditions. A 17-mi/h difference in penetration speeds between the Cessna 172 and the Cherokee windshields is evident (figure 13).

SET No. 5a. A fifth set of four runs (ALS-18 through 21) was made, as in set No. 4, but with the addition of an accelerometer located on a flat, milled surface of the PAR-38 holder (figure 14). These runs were made at about 41, 41, 47, and 50 mi/h. The first run at 41 mi/h was repeated due to a lack of oscillograph data. Windshields were penetrated at 47 and 50 mi/h, and the maximum "g" ratings were 168 and 156, respectively (figure 15).

SET No. 5b. One run (ALS-41) was carried out with the Cessna 172 windshield and the PAR-38 lamp and holder, with the accelerometer attached as in set No. 5a (figure 16). This run, at 27 mi/h, penetrated the windshield and gave a maximum accelerometer reading of about 156 g's. As might be expected, this is the same "g" reading that was obtained when the Cherokee 180 windshield was penetrated. The speed of impact was, however, quite different, being 50 mi/h for the smaller windshield as compared to the above 27 mi/h. Copies of the oscillograph recordings are included in this report as figures 17, 18, 19, and 20. Tenth-of-a-second markers are shown as vertical lines 1 1/2 inches apart.

SET No. 6. To obtain data under the most favorable impact conditions, this set was performed with the face of the PAR-38 lamp striking flat against the Cherokee 180 windshield (figure 21). Nine runs were made (ALS-42 through 50) at speeds of 30, 36, 40, 45, 50, 54, 61, 65, and 69 mi/h. The run at 69 mi/h penetrated the windshield. This indicates that under the most favorable conditions, the lamp will simply bounce off the windshield up to 69 mi/h. Beyond this speed, it appears likely that the lamp, under ideal conditions, will penetrate the windshield.

SET No. 7. Lastly, it was decided to take the other extreme from set No. 6 and impact the Cherokee 180 windshield into the PAR-38 lamp and holder under the worst conditions (with the sharp points of the holder striking the windshield) (figure 22). Two runs (51 and 52) were run at speeds of 30 and 41 mi/h, with the run at 41 mi/h breaking the windshield. The penetration speed difference of 28 mi/h between ideal lamp attitude and worst lamp attitude is significant. This shows that the attitude of the lamp determines, to a great extent, the speed at which it will penetrate the windshield.

A corollary finding was that the catapult method of impact testing is expensive. The reason for using this method was the seemingly substantial validity of this method in replicating the mechanical forces and structural effects of aircraft accidents. It is quite possible, however, that a laboratory test method could be developed and shown to have the power to duplicate the more costly large-scale crash tests.

This has been done in many areas of engineering testing with good results. Since additional frangibility testing, including other lamps, aircraft, weather conditions, and effects, may be conducted, small-scale tests should be conducted to determine the feasibility of standardizing lamp impact/frangibility test methods with less costly procedures.

INTERPRETATION OF RESULTS.

Table 1 summarizes all the test results and approximate speeds. From these results, it can be seen that windshields were penetrated in all test series when the higher speeds were used. Still, the maximum speed in the tests was near or below the impact speed that would be expected in an actual undershoot accident. Hence, it is clear that the lamps and holders are not truly frangible.

Comparison across the lamp and holder conditions indicates, as expected, that the heavier assemblies penetrated the windshields at the lower impact speeds. Also, impact with sharp edges resulted in penetration at lower speeds. Penetration of the windshields occurred from speeds of 24 mi/h with the heavy PAR-56 lamp and holder to 69 mi/h with the lighter PAR-38 lamp and holder at the ideal impact attitude. The plexiglas of the general aviation windshields was such that all lamps either dimpled the windshield and bounced off (figure 23 gives an example of this), or cut straight through the windshield. The safety of a pilot in a cockpit would certainly be in jeopardy if one of these lamps should hit a windshield of a general aviation type plane, even under the slowest of flying conditions.

To protect the pilot from approach lamp penetration, it would seem necessary to make the lamp units either of a very frangible material or to make them in a shape (perhaps round) that would bounce off the windshield, or both. Design of such is conceivable. Since the PAR-56 lamp is much stronger than the typical windshield, it would seem necessary to develop a new lamp to attain true frangibility.

CONCLUSIONS

From the tests conducted, the following is concluded:

1. General aviation windshields are easily penetrated by the PAR-38 or PAR-56 ALS lamps and holders at less than usual flying speeds.

2. A safe ALS lamp should self-destruct on windshield impact without high risk to the pilot at speeds up to normal touchdown velocity (70 to 80 mi/h for small aircraft).

3. New lamps and holders must be developed to produce a truly "safe" approach lighting system lamp.

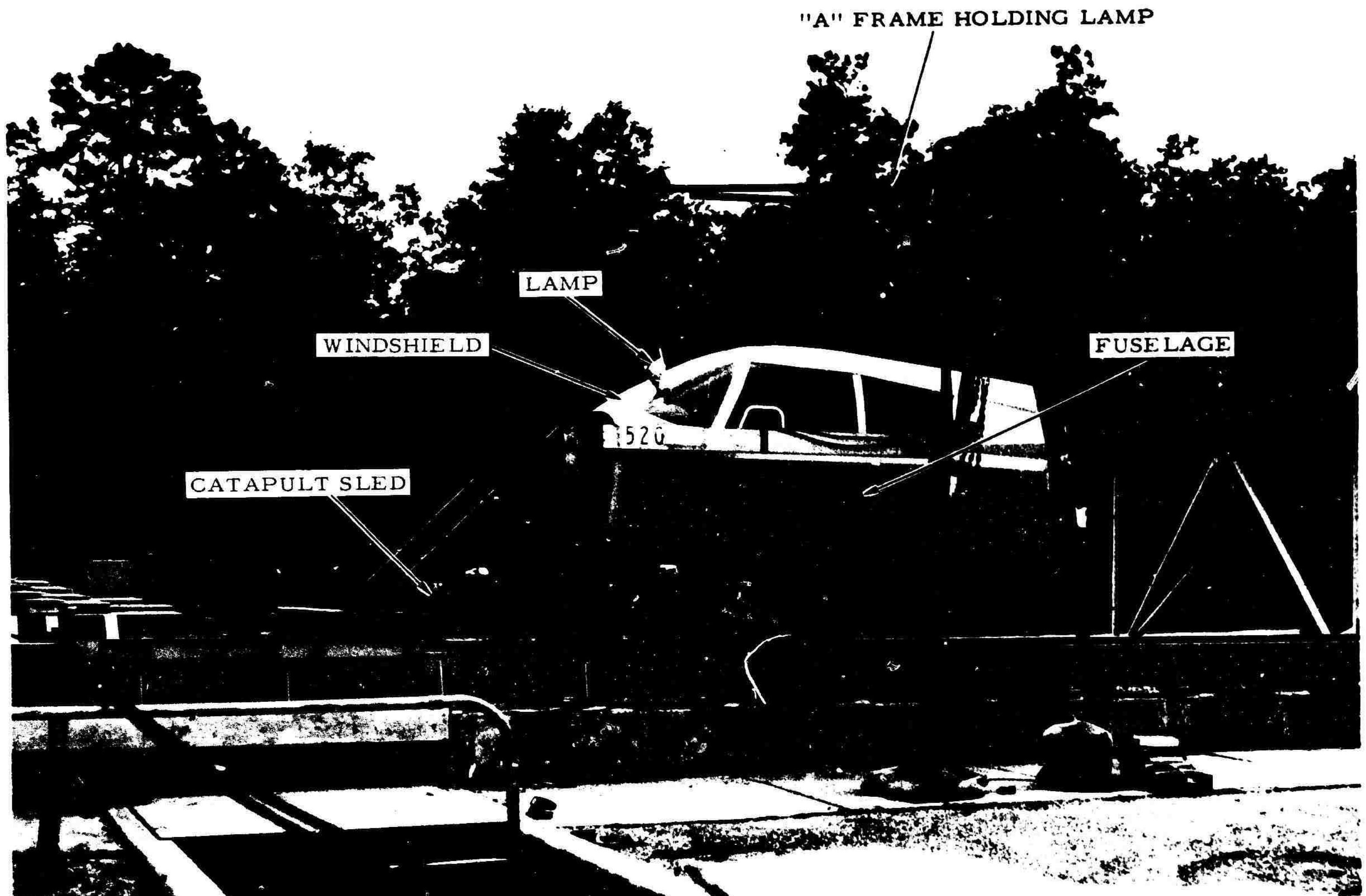
RECOMMENDATIONS

Having demonstrated that the present ALS lamps and fixtures are not truly frangible, the following is recommended:

1. Further testing should explore other parameters, such as cold-weather testing and the use of other types of lamps and windshields.

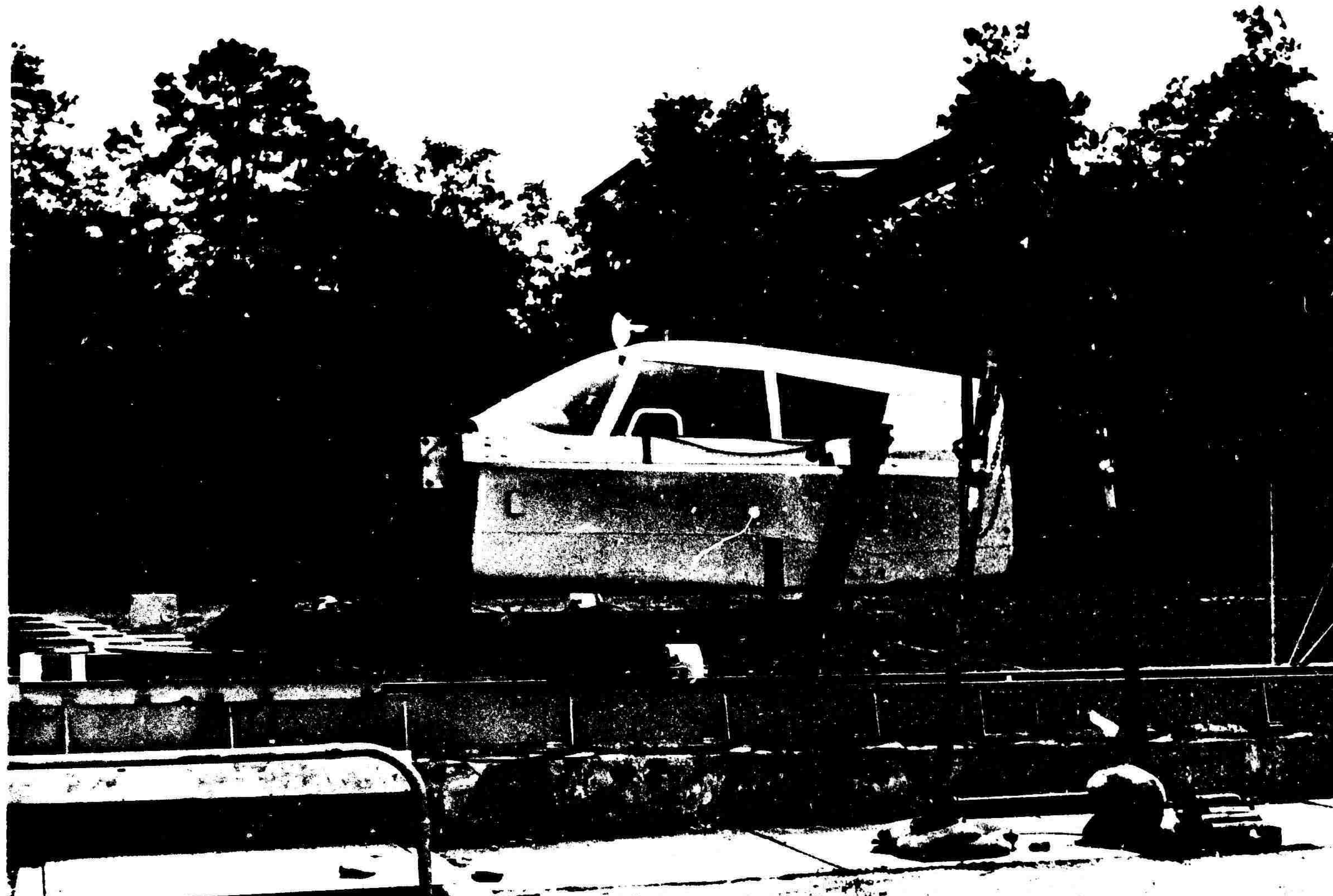
2. A so-called "safe" lamp for future approach lighting systems should be developed.

3. A simple and accurate test method should be developed for testing the frangibility of approach lights at any location, with a minimum of specialized test equipment.



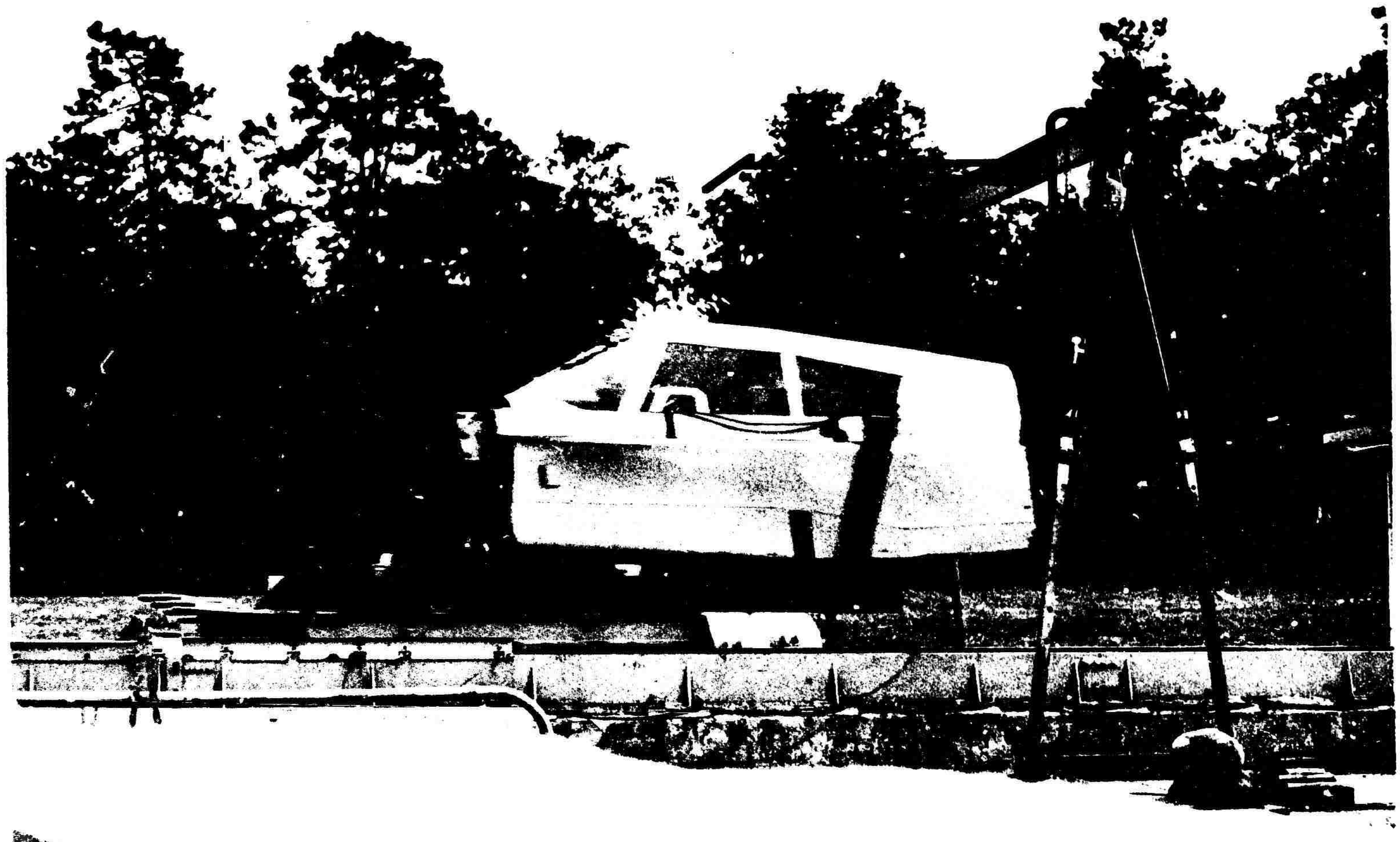
75-8-1

FIGURE 1. CATAPULT LAMP FRANGIBILITY TEST SETUP



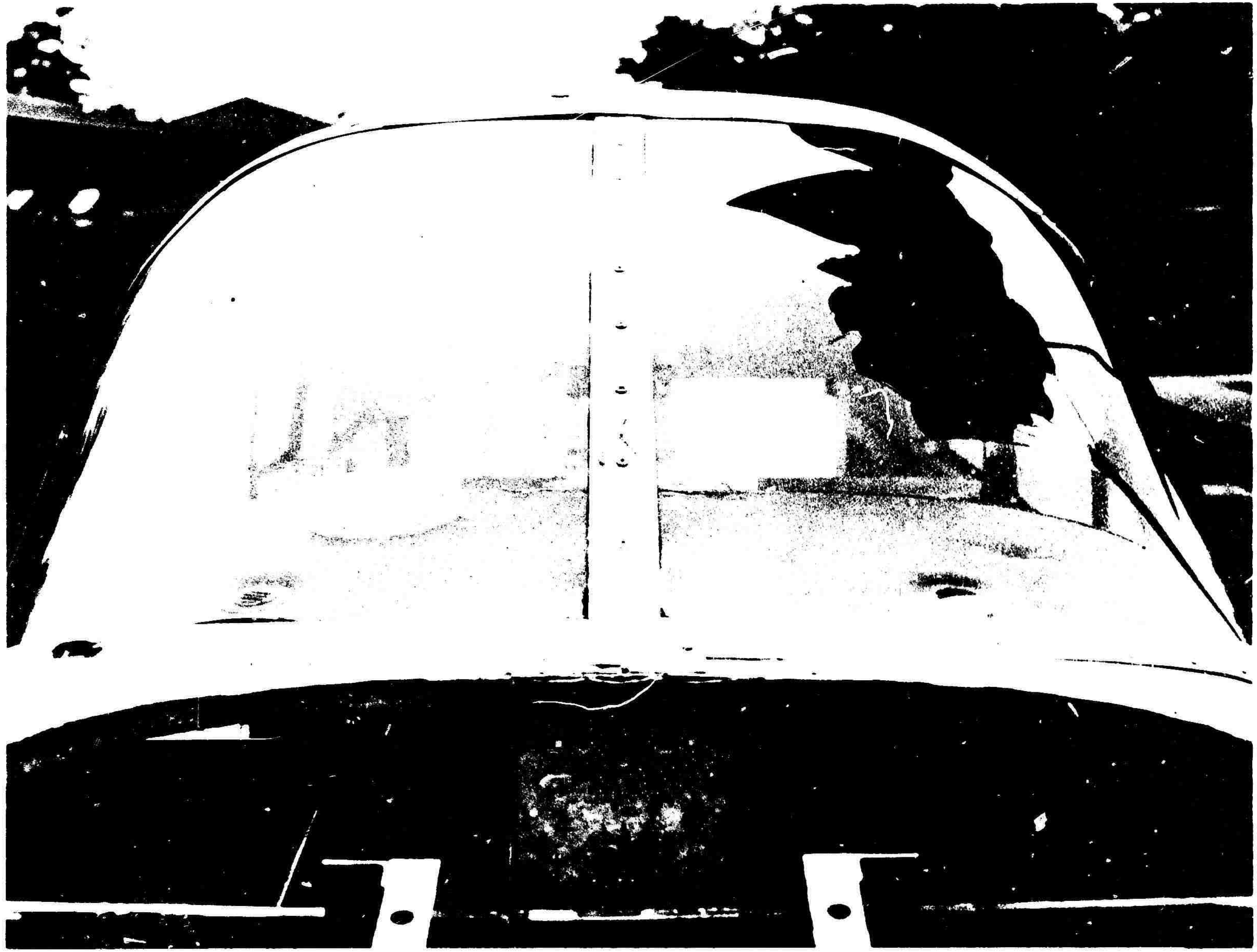
75-8-2

FIGURE 2. LAMP/WINDSHIELD, NONPENETRATING IMPACT TEST



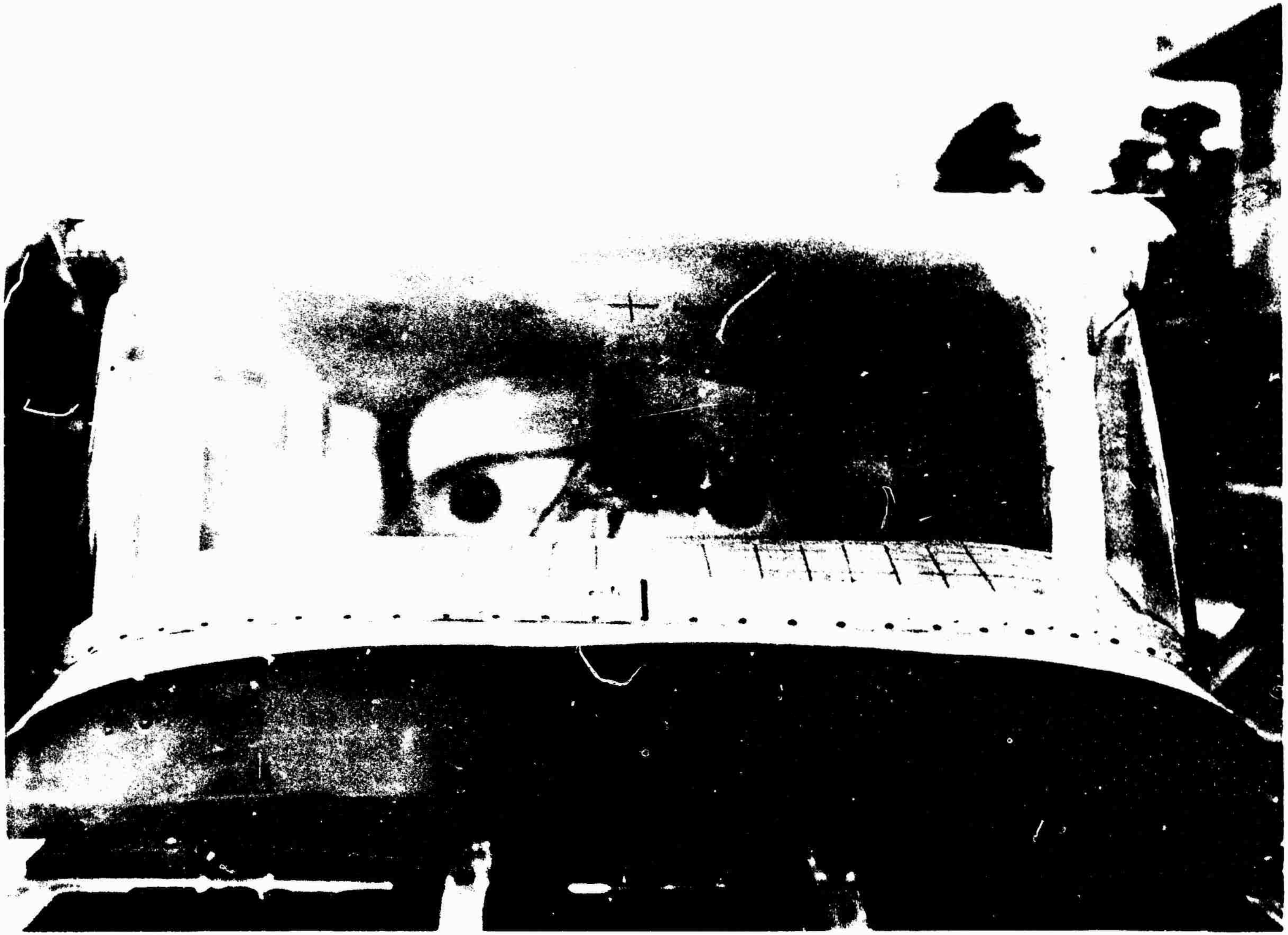
75-8-3

FIGURE 3. LAMP/WINDSHIELD, PENETRATING IMPACT TEST



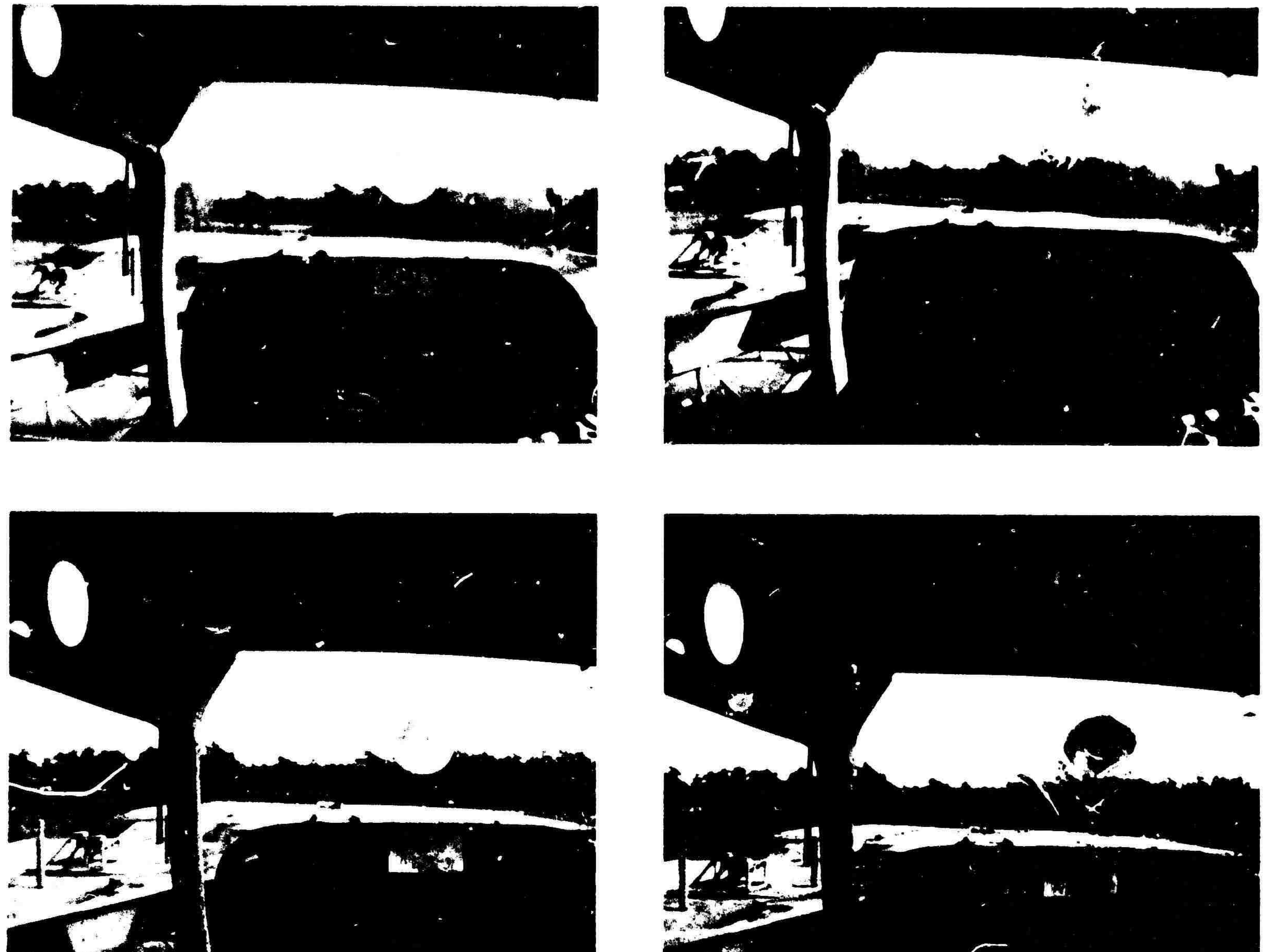
75-9-4

FIGURE 4. CHEROKEE 180 WITH WINDSHIELD BROKEN BY LAMP PENETRATION



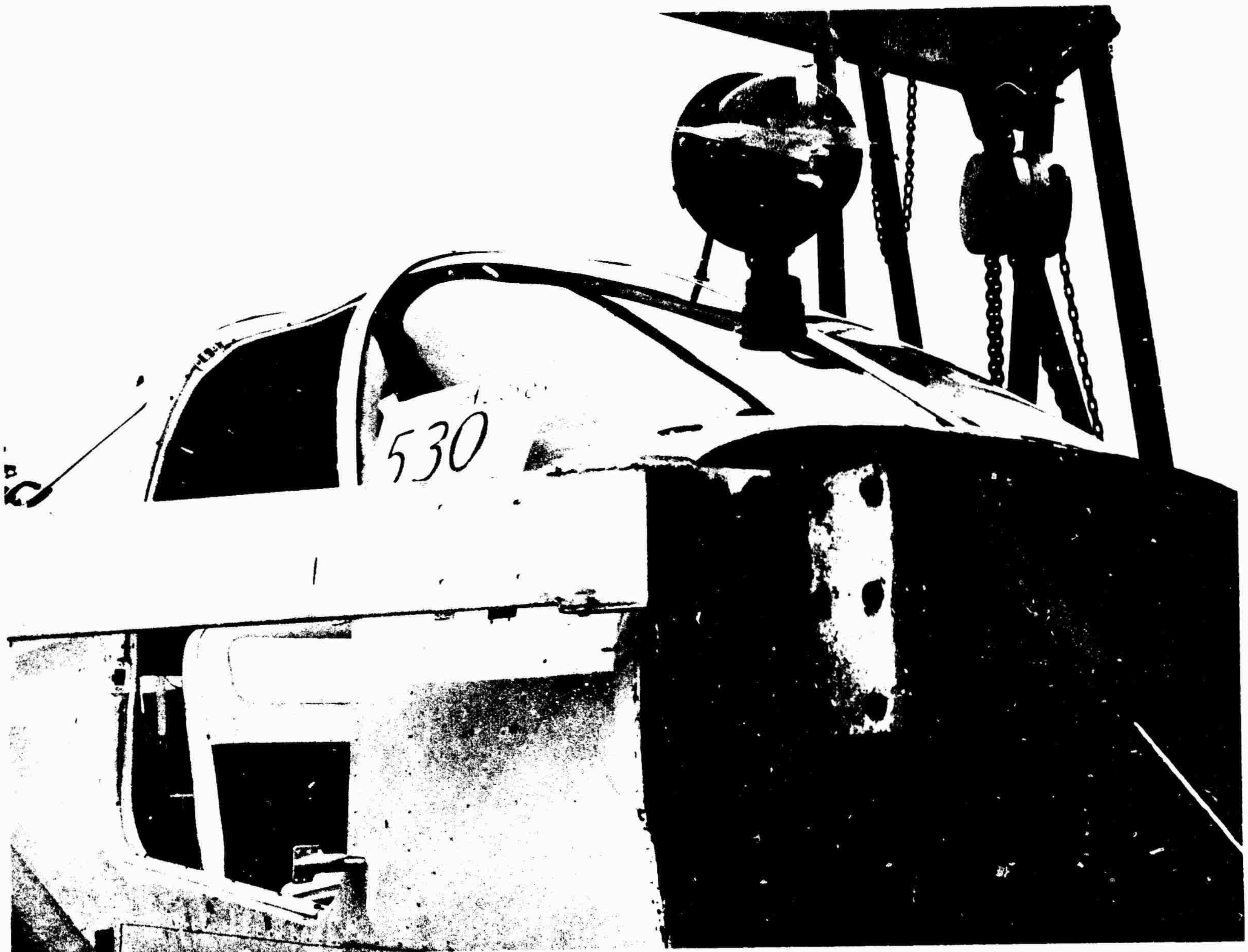
75-8-5

FIGURE 5. CESSNA 172 WINDSHIELD SHOWING IMPACT POINT



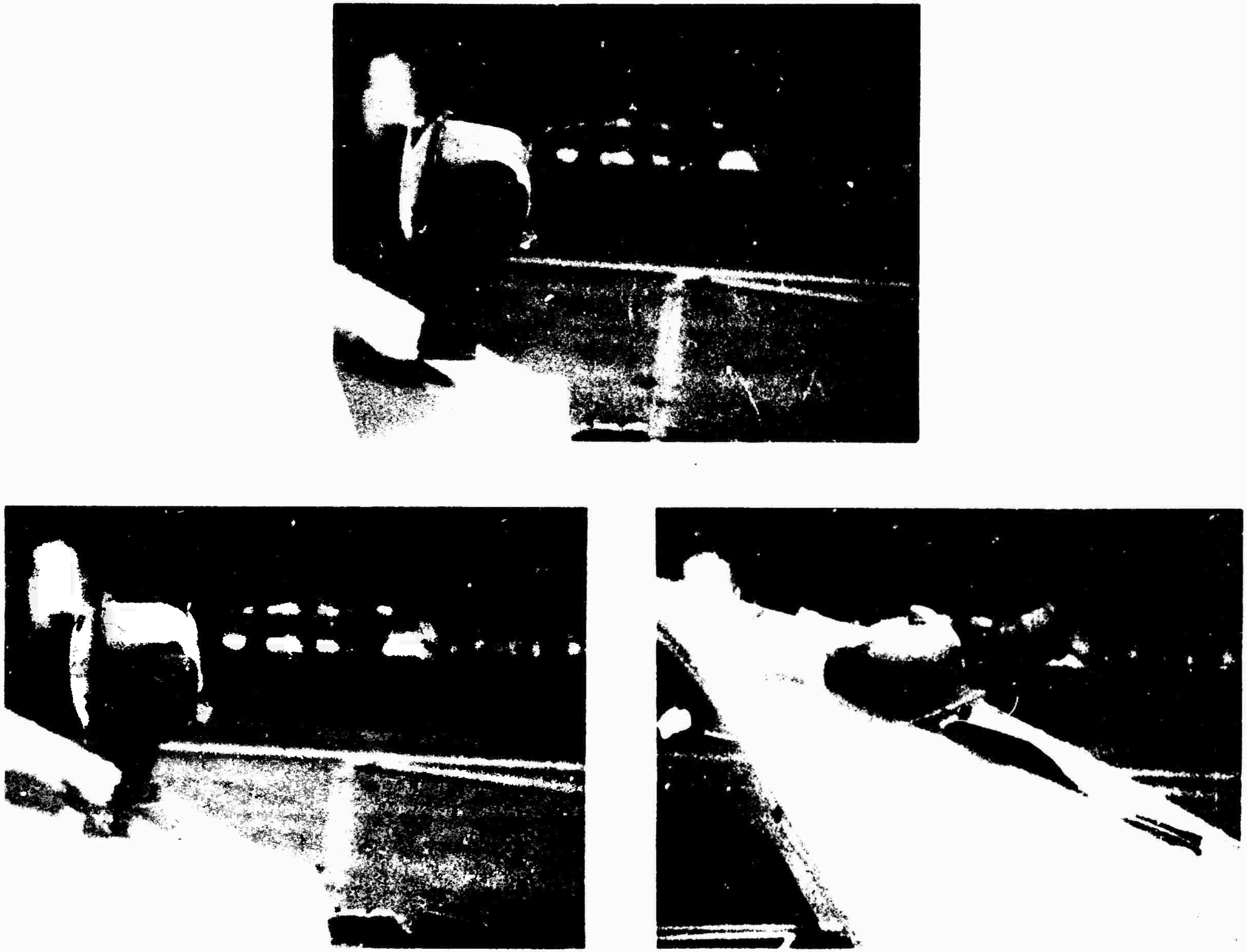
75-8-6

FIGURE 6. TYPICAL PHOTOGRAPHS OF TEST SET NO. 1b



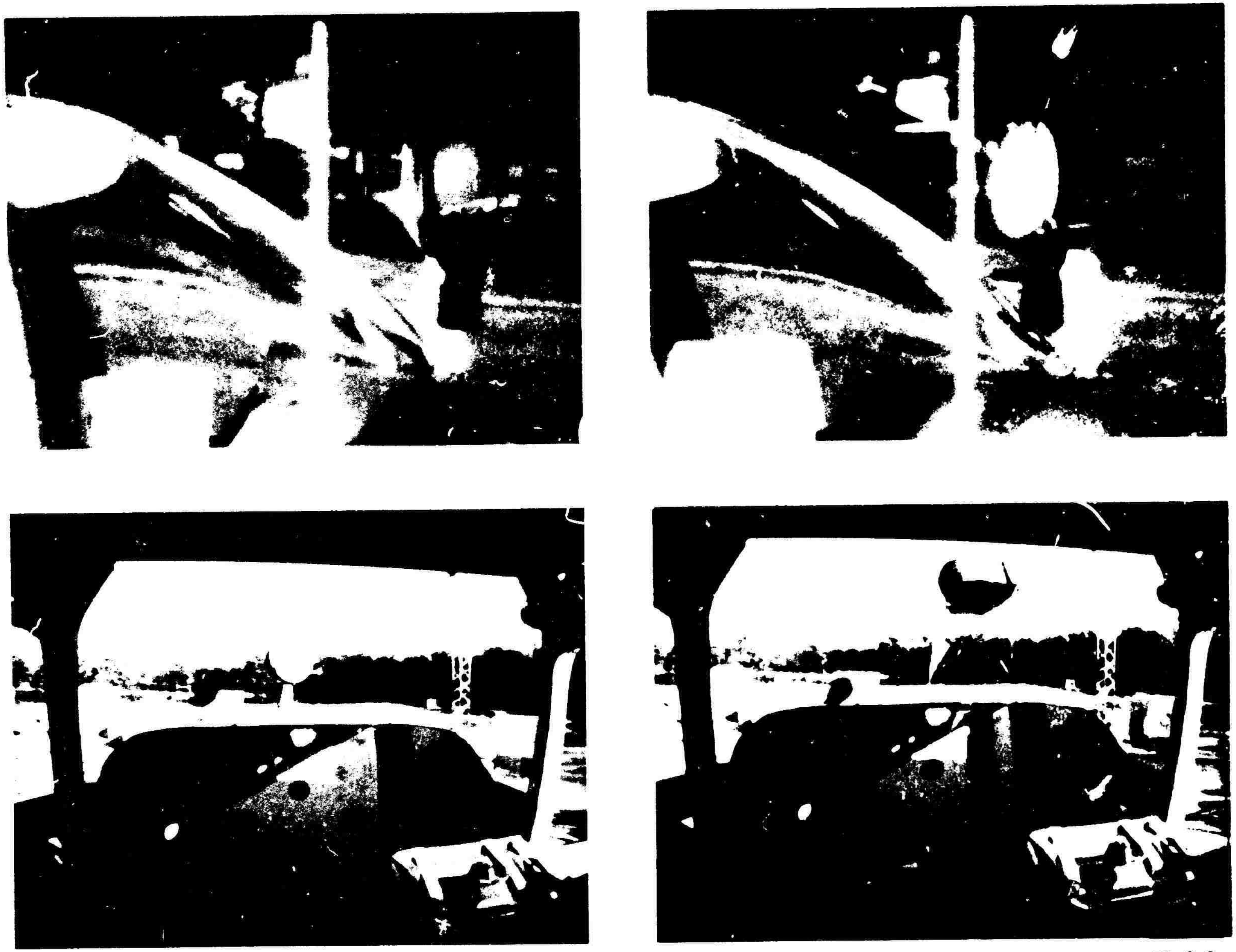
75-8-7

FIGURE 7. PAR-56 LAMP AND HOLDER IN TEST POSITION



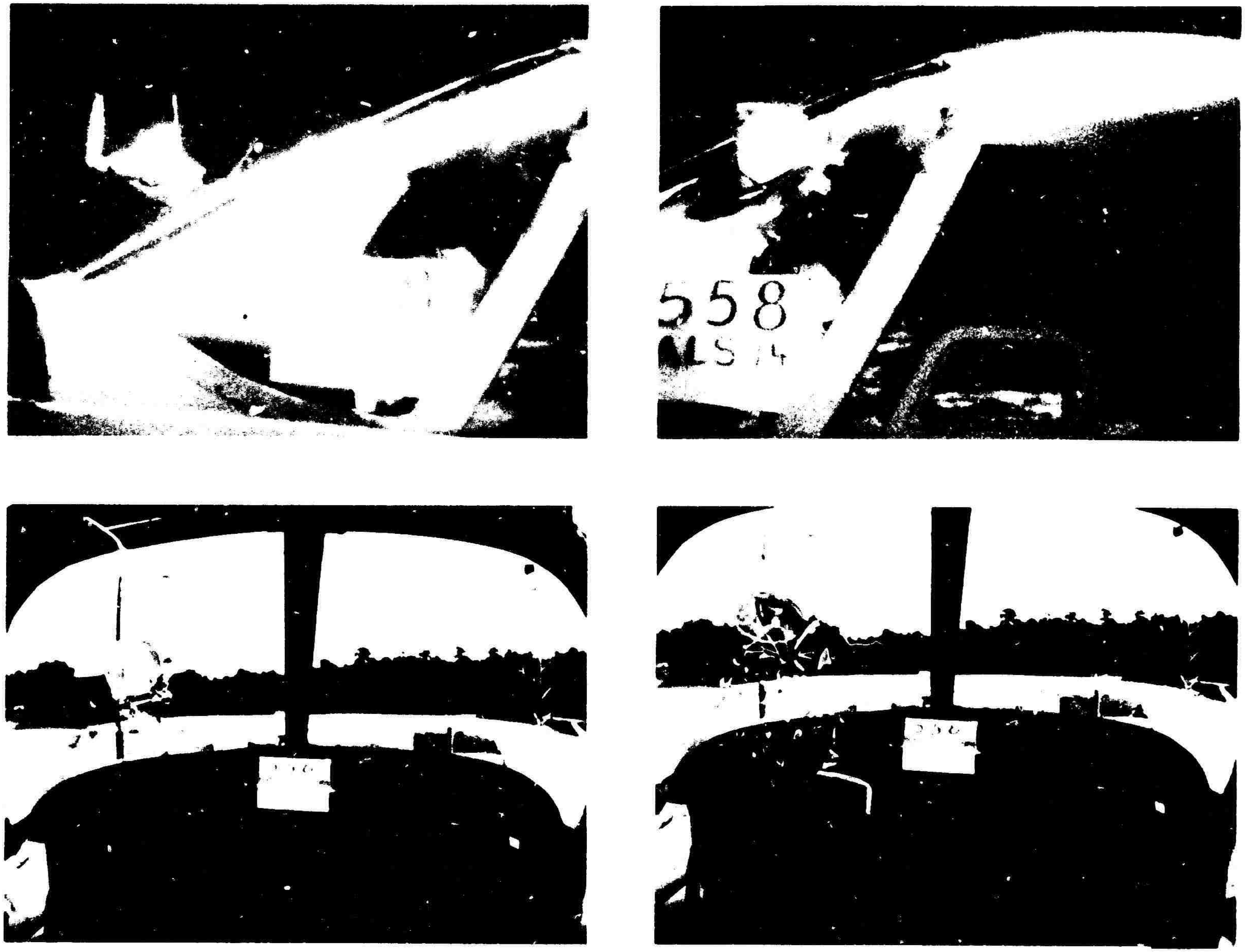
75-8-8

FIGURE 8. TYPICAL PHOTOGRAPHS OF TEST SET NO. 2a



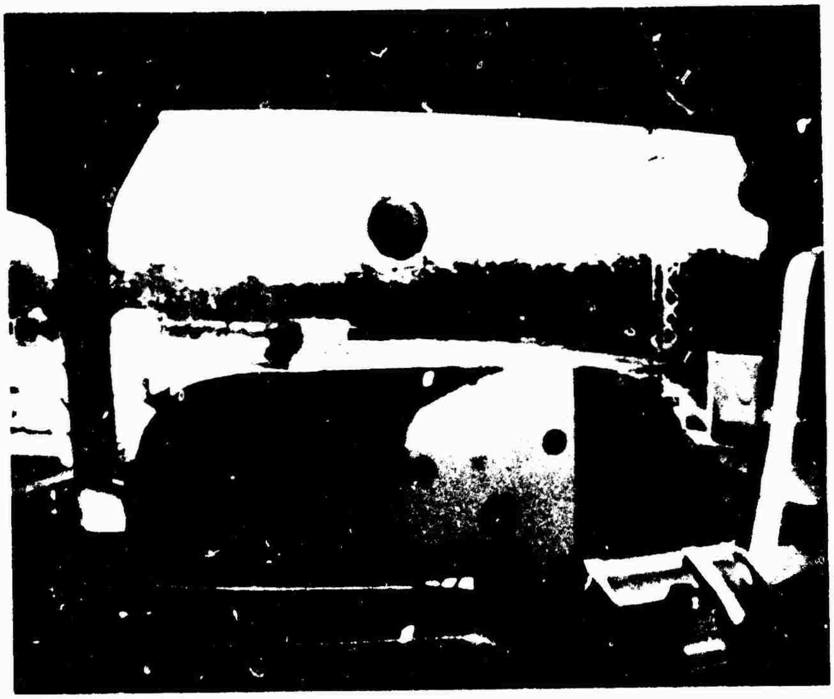
75-8-9

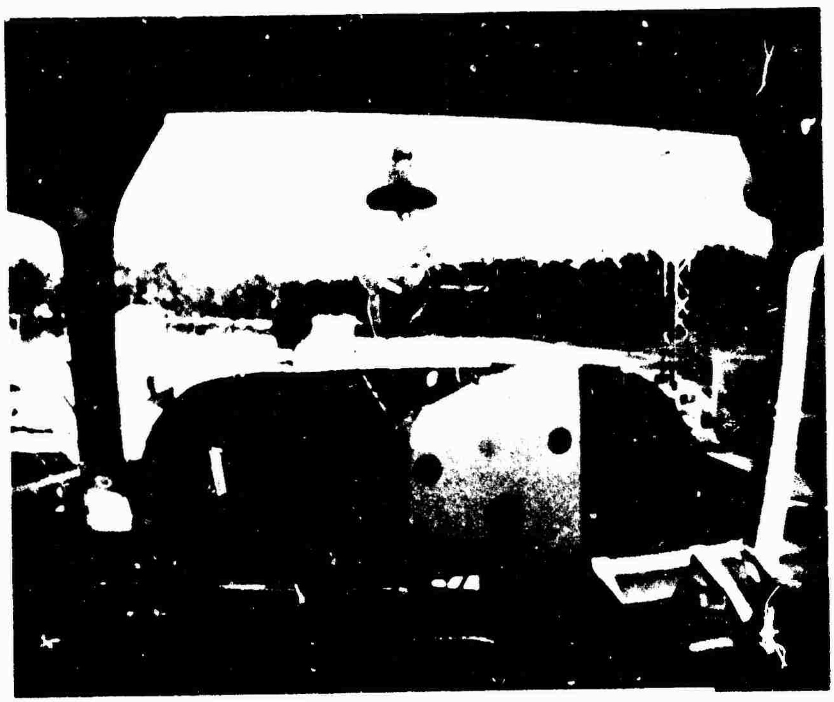
FIGURE 9. TYPICAL PHOTOGRAPHS OF TEST SET NO. 2b



75-8-10

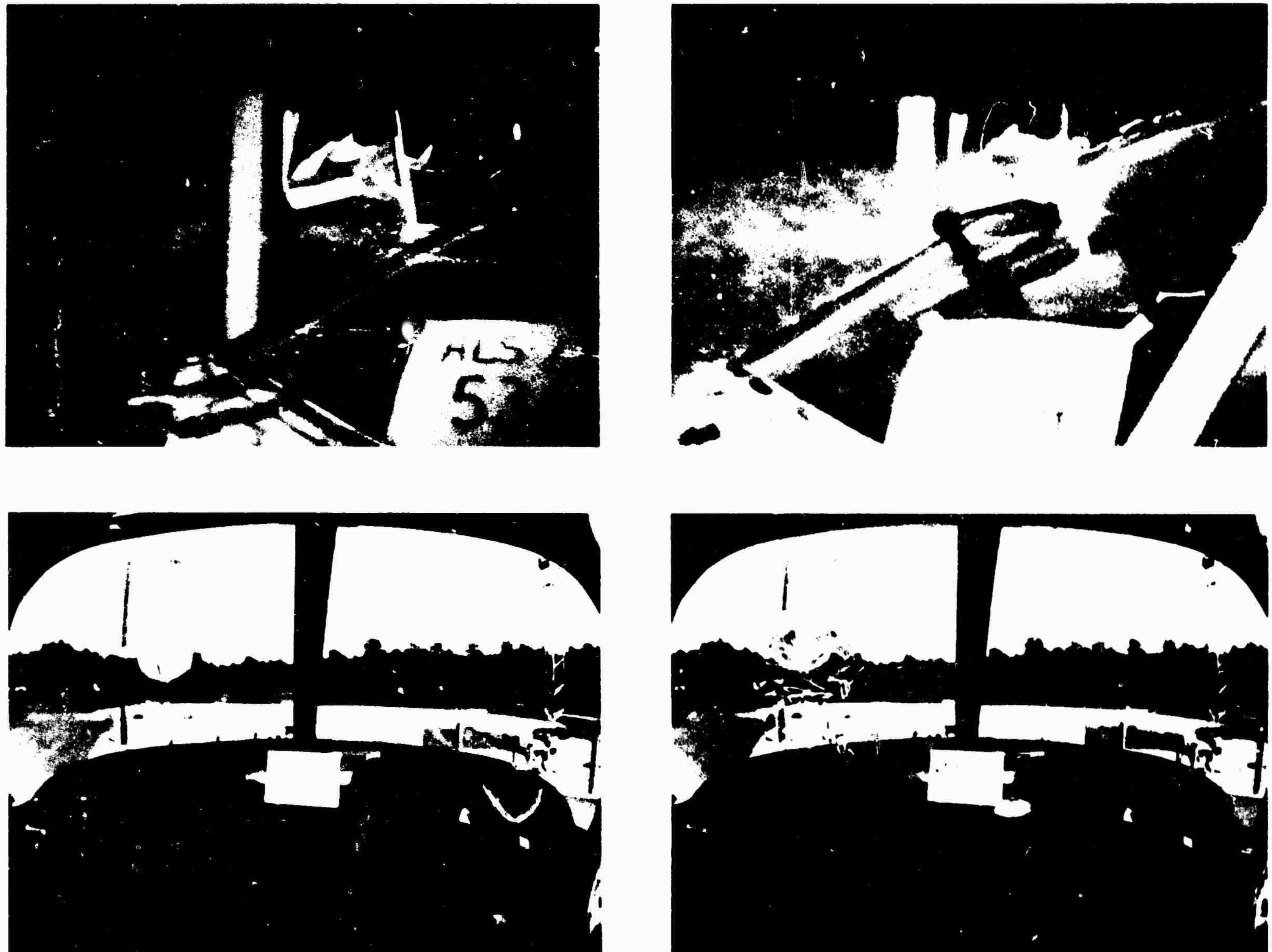
FIGURE 10. TYPICAL PHOTOGRAPHS OF TEST SET NO. 3a





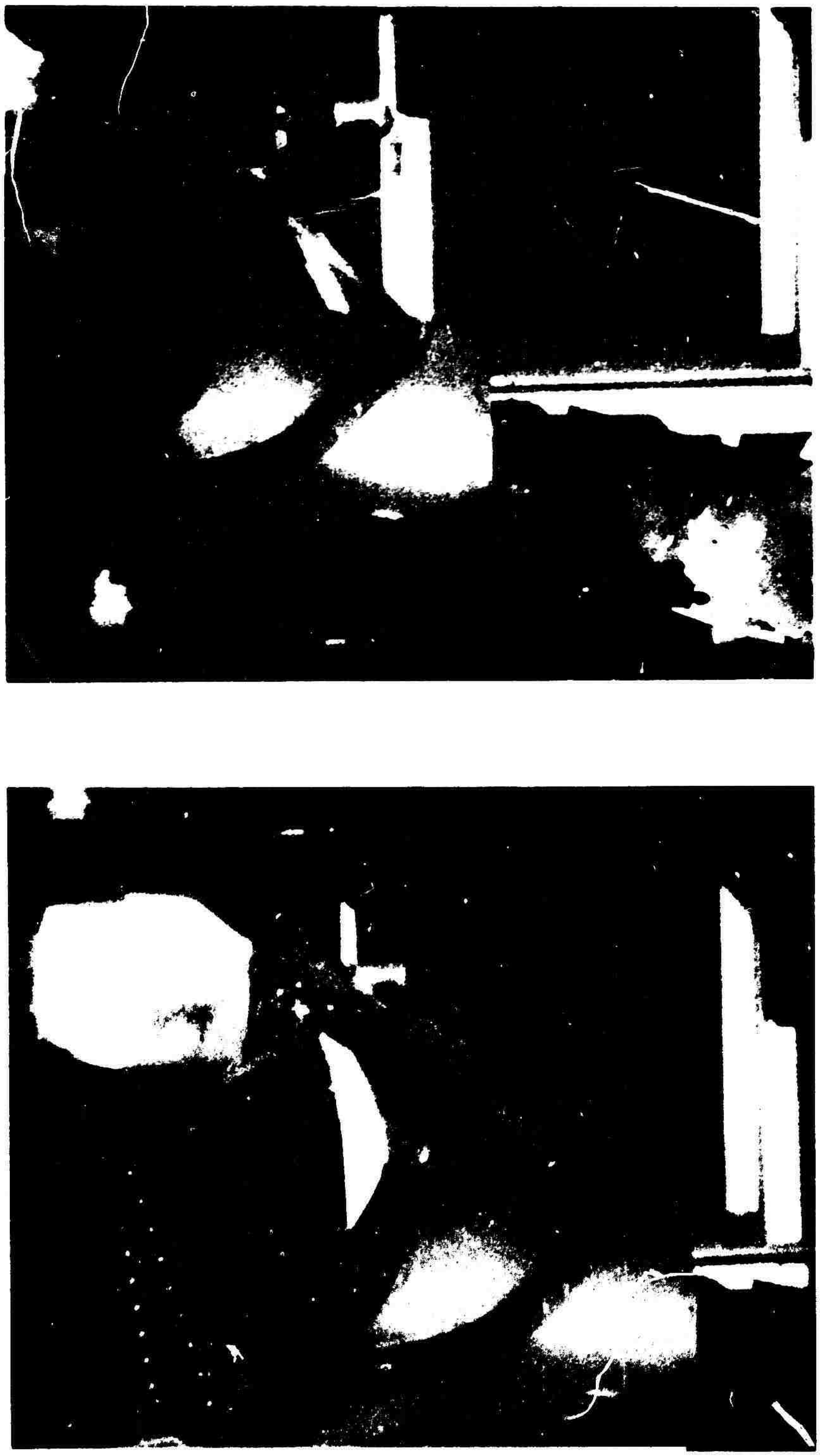
75-8-11

FIGURE 11. TYPICAL PHOTOGRAPHS OF TEST SET NO. 3b



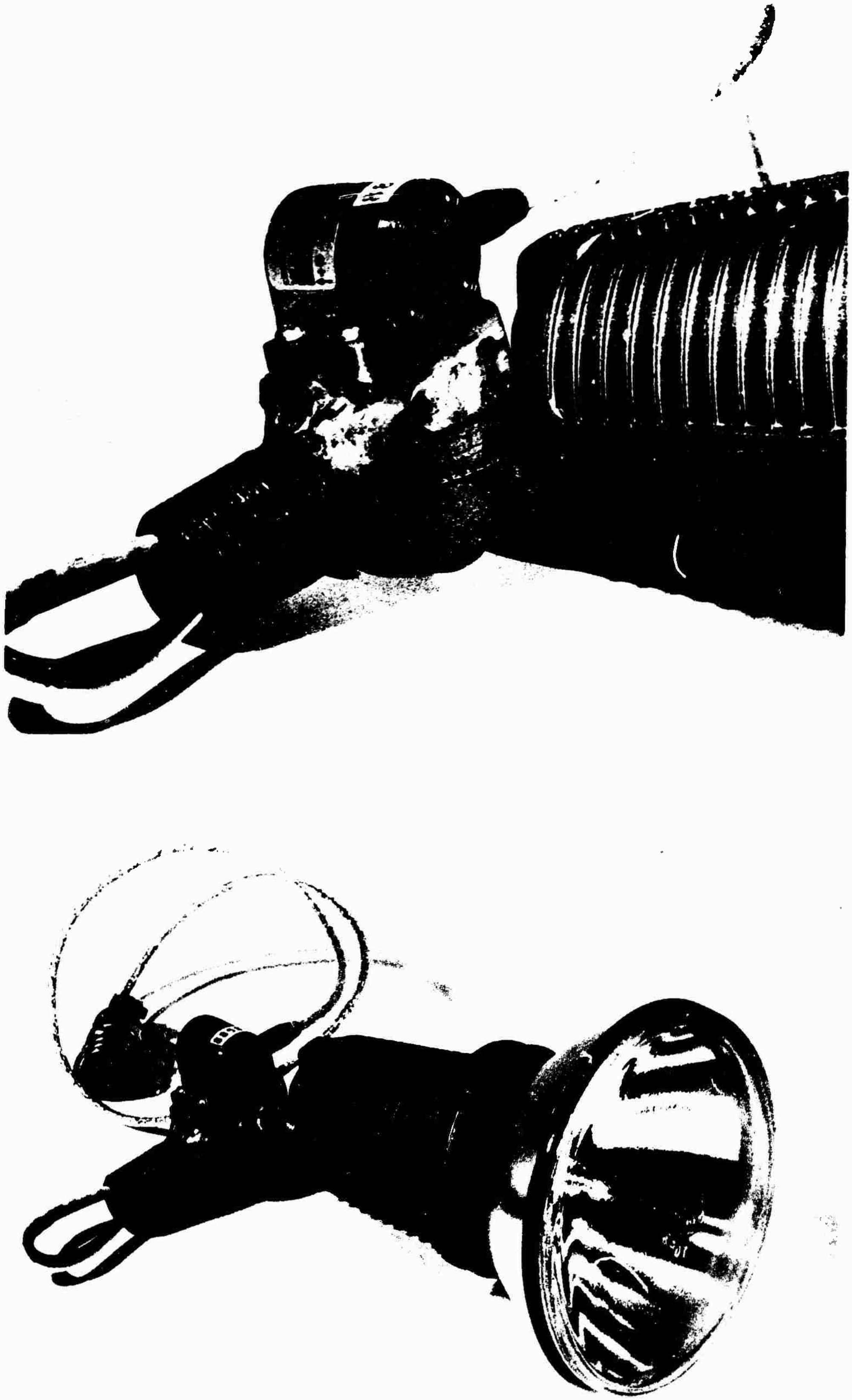
75-8-12

FIGURE 12. TYPICAL PHOTOGRAPHS OF TEST SET NO. 4a



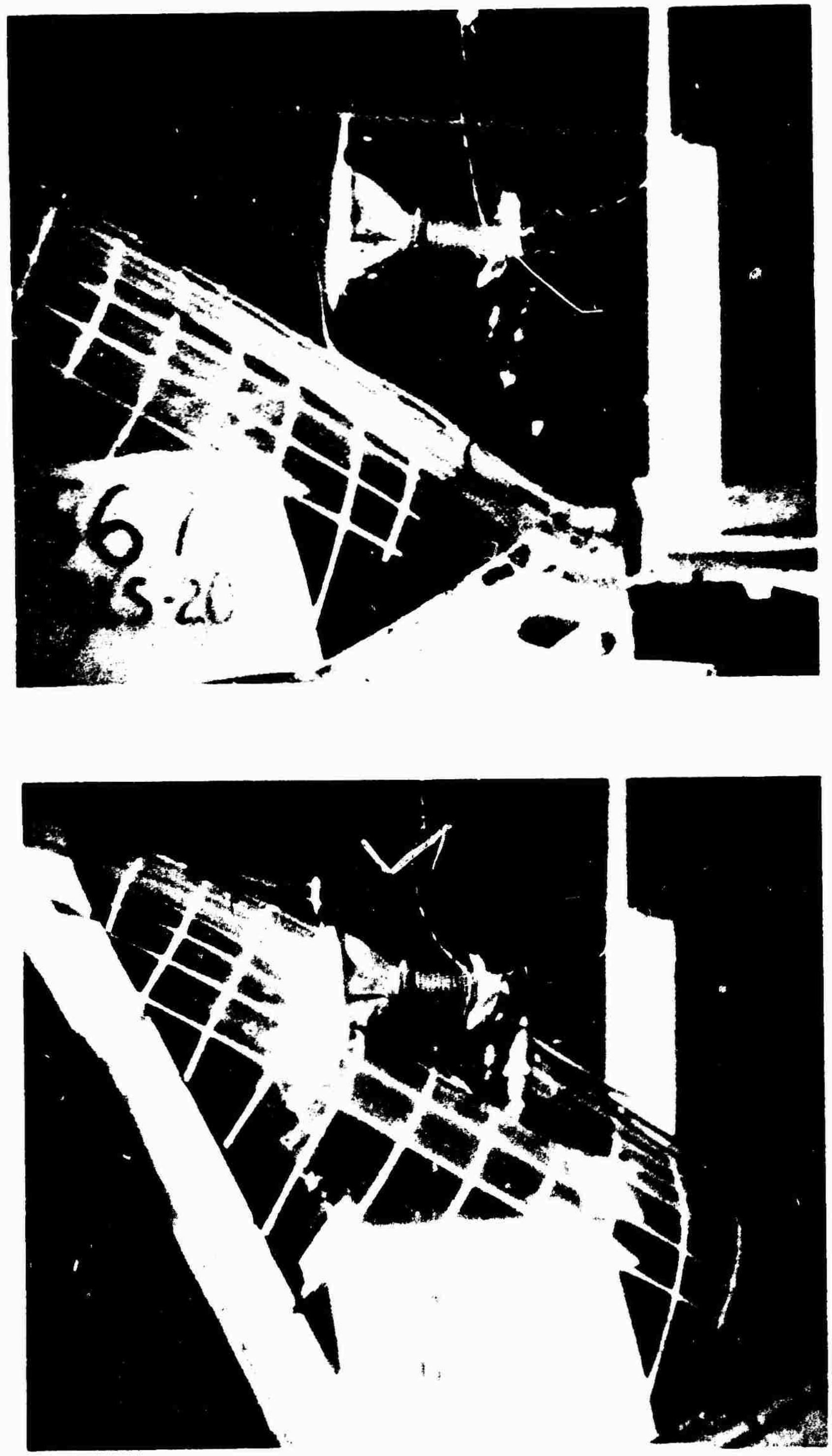
75-8-13

FIGURE 13. TYPICAL PHOTOGRAPHS OF TEST SET NO. 4b



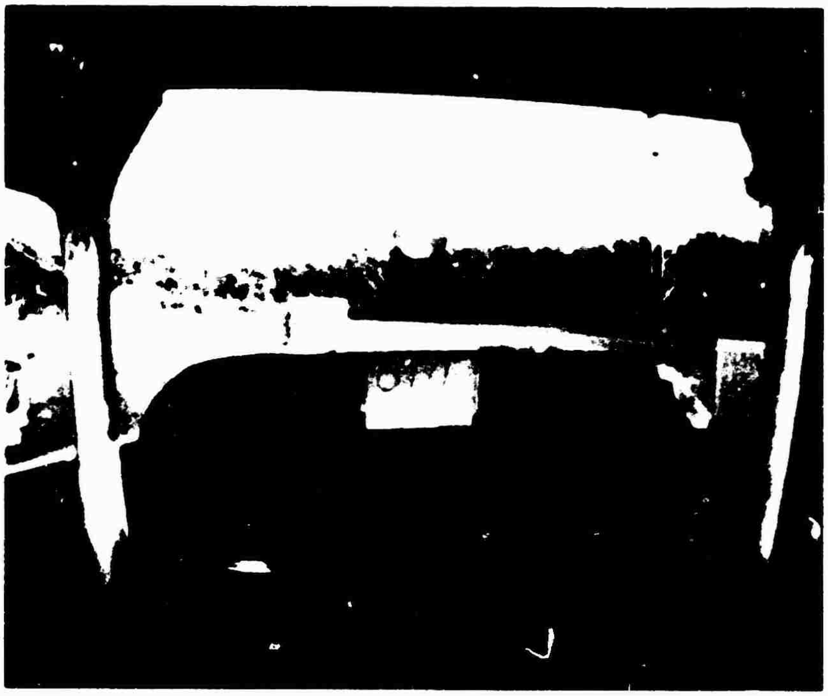
75-8-14

FIGURE 14. ACCELEROMETER ATTACHED TO PAR-38 LAMPHOLDER



75-8-15

FIGURE 15. TYPICAL PHOTOGRAPHS OF TEST SET NO. 5a



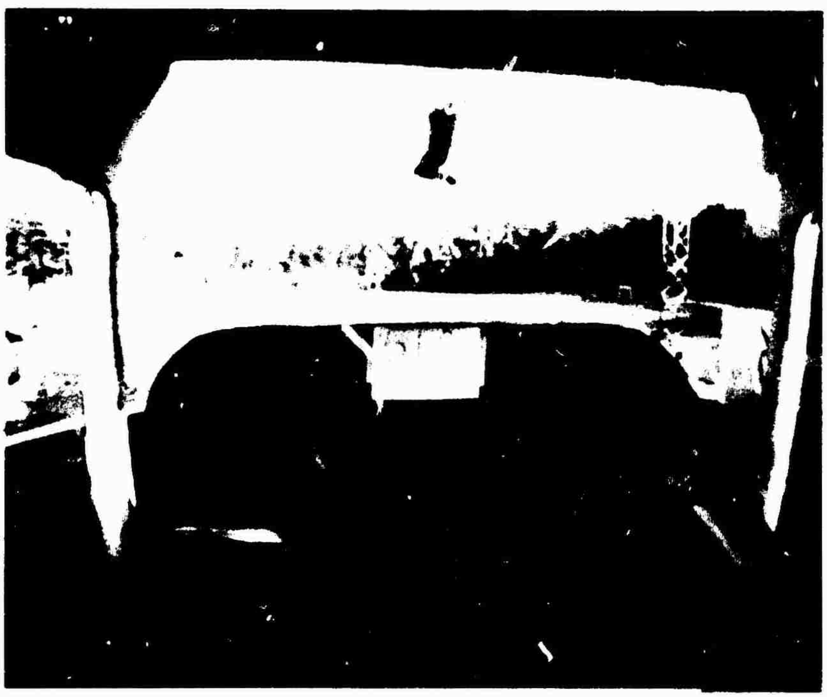


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FIGURE 16. TYPICAL PHOTOGRAPHS OF TEST SET NO. 5b

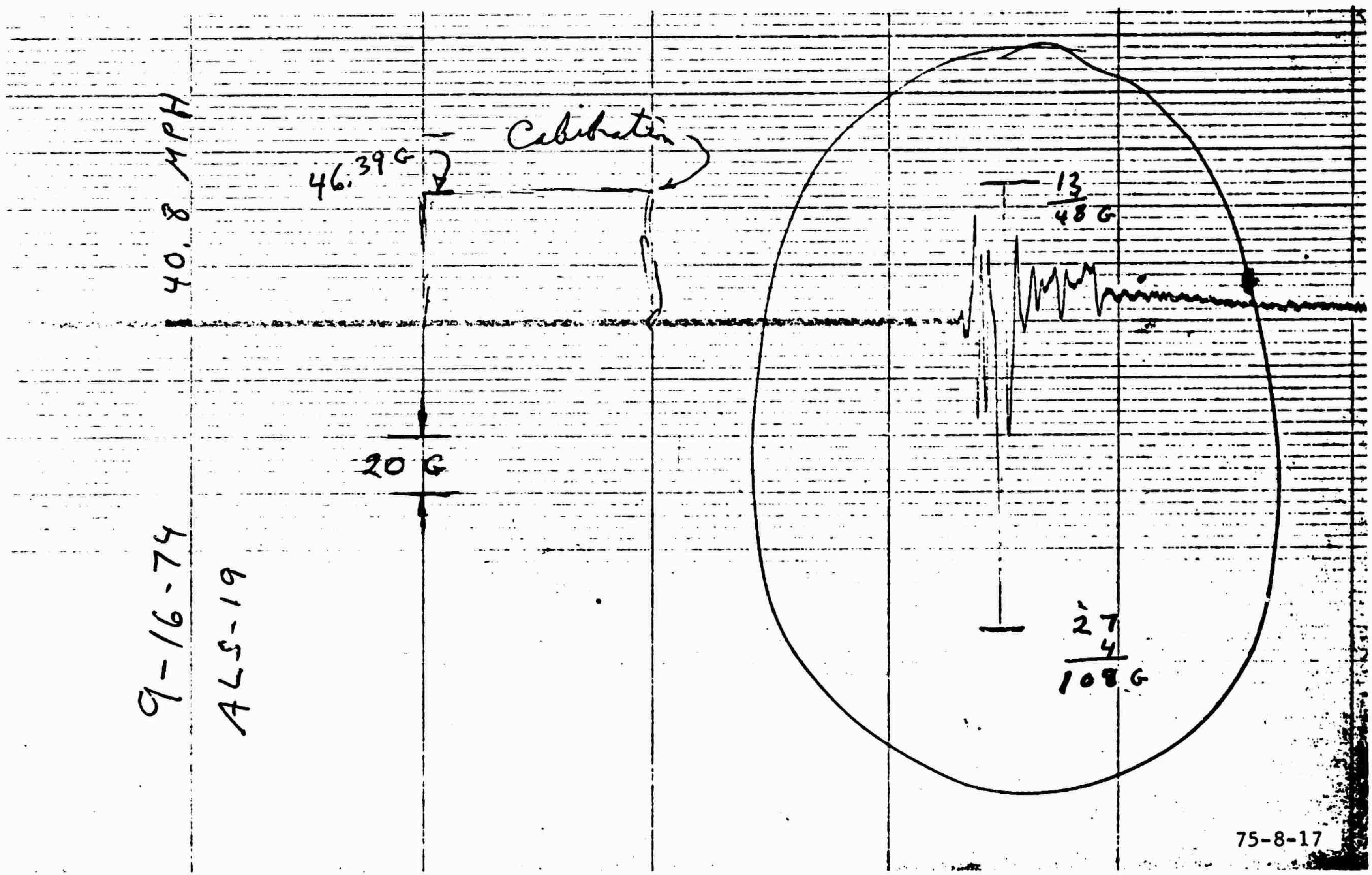

FIGURE 17. ACCELEROMETER OSCILLOGRAPH RECORDING OF ALS-19 (RAW DATA)

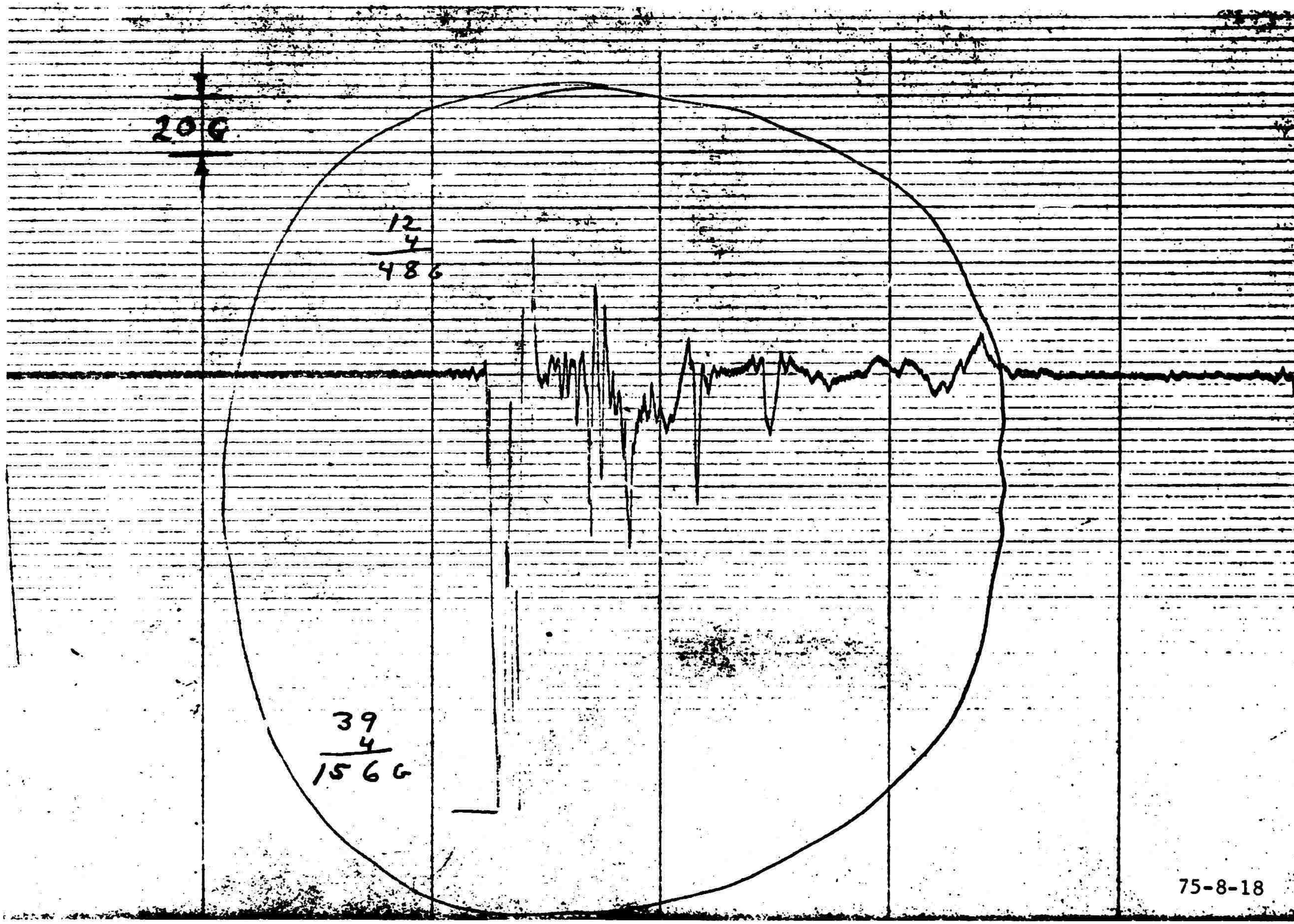

FIGURE 18. ACCELEROMETER OSCILLOGRAPH RECORDING OF ALS-20 (RAW DATA)

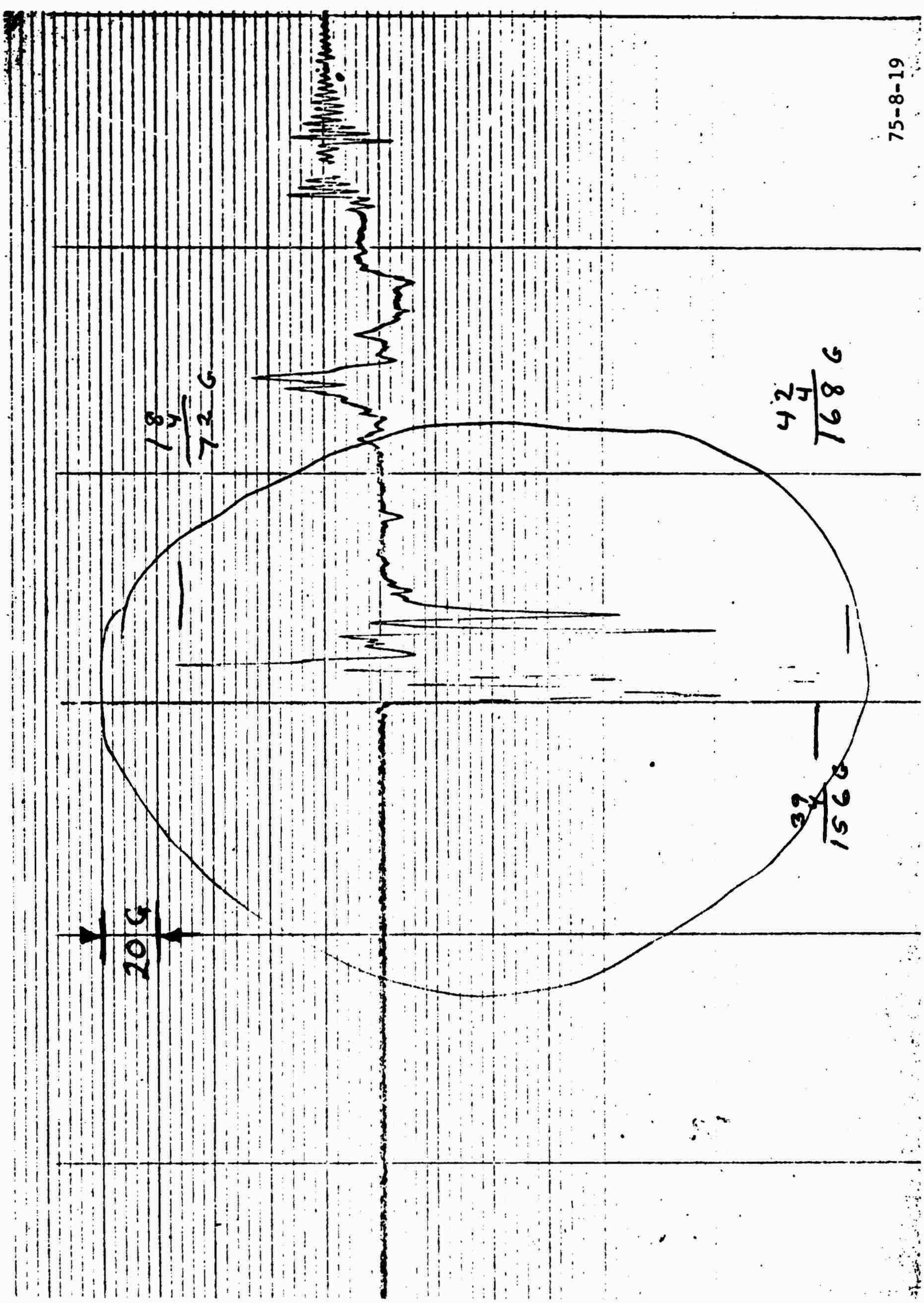

FIGURE 19. ACCELEROMETER OSCILLOGRAPH RECORDING OF ALS-21 (RAW DATA)

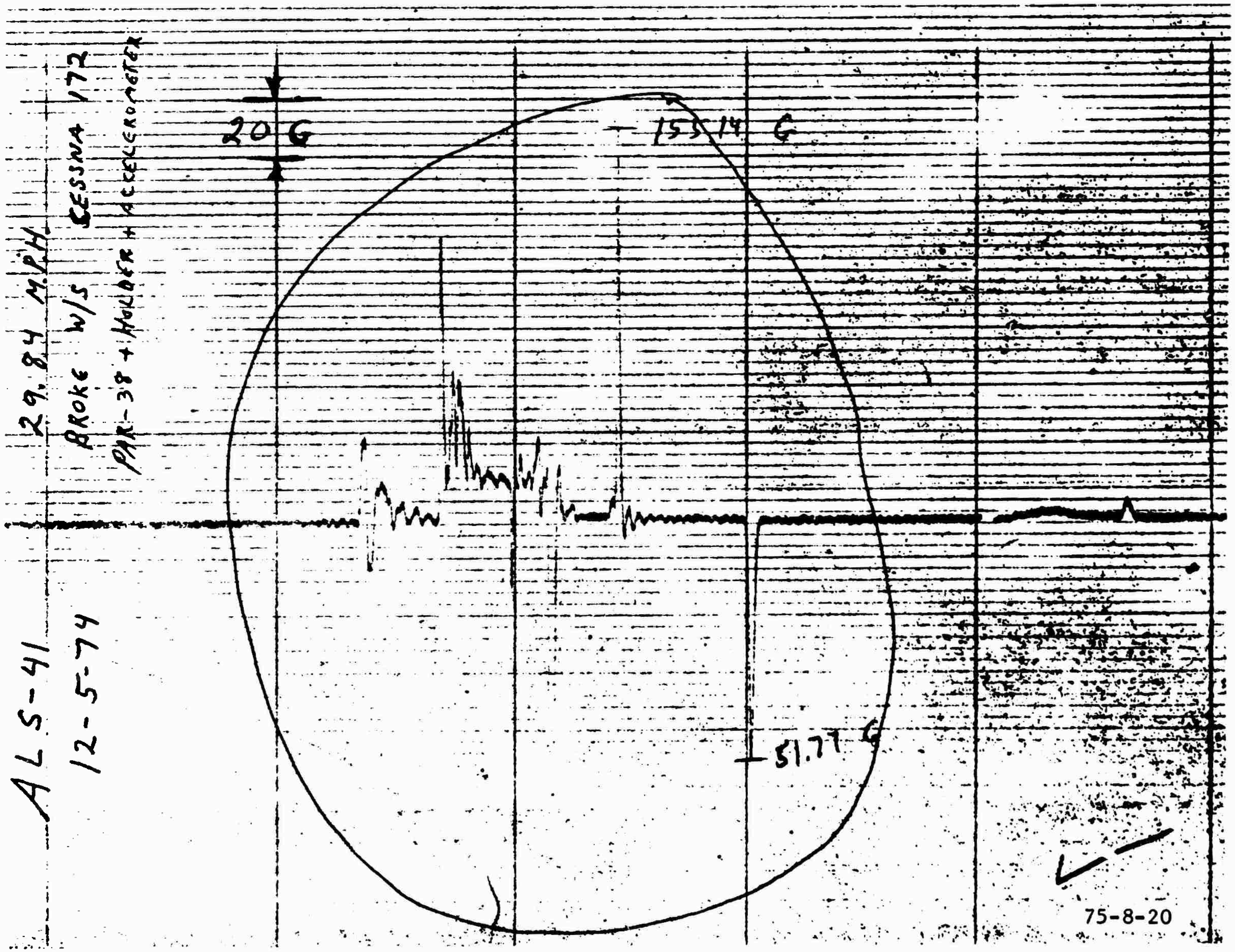

FIGURE 20. ACCELEROMETER OSCILLOGRAPH RECORDING OF ALS-41 (RAW DATA)

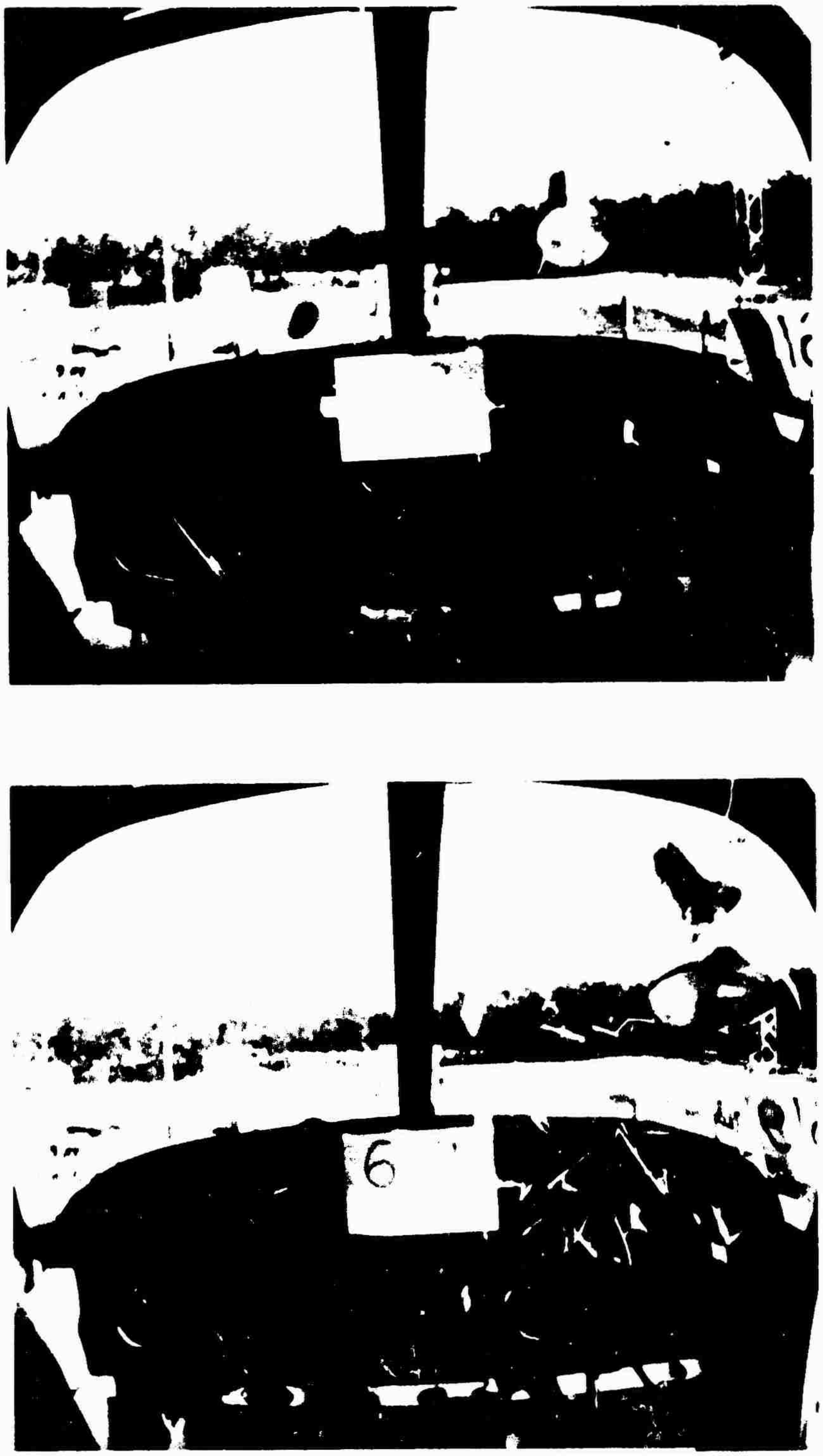

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FIGURE 21. TYPICAL PHOTOGRAPHS OF TEST SET NO. 6

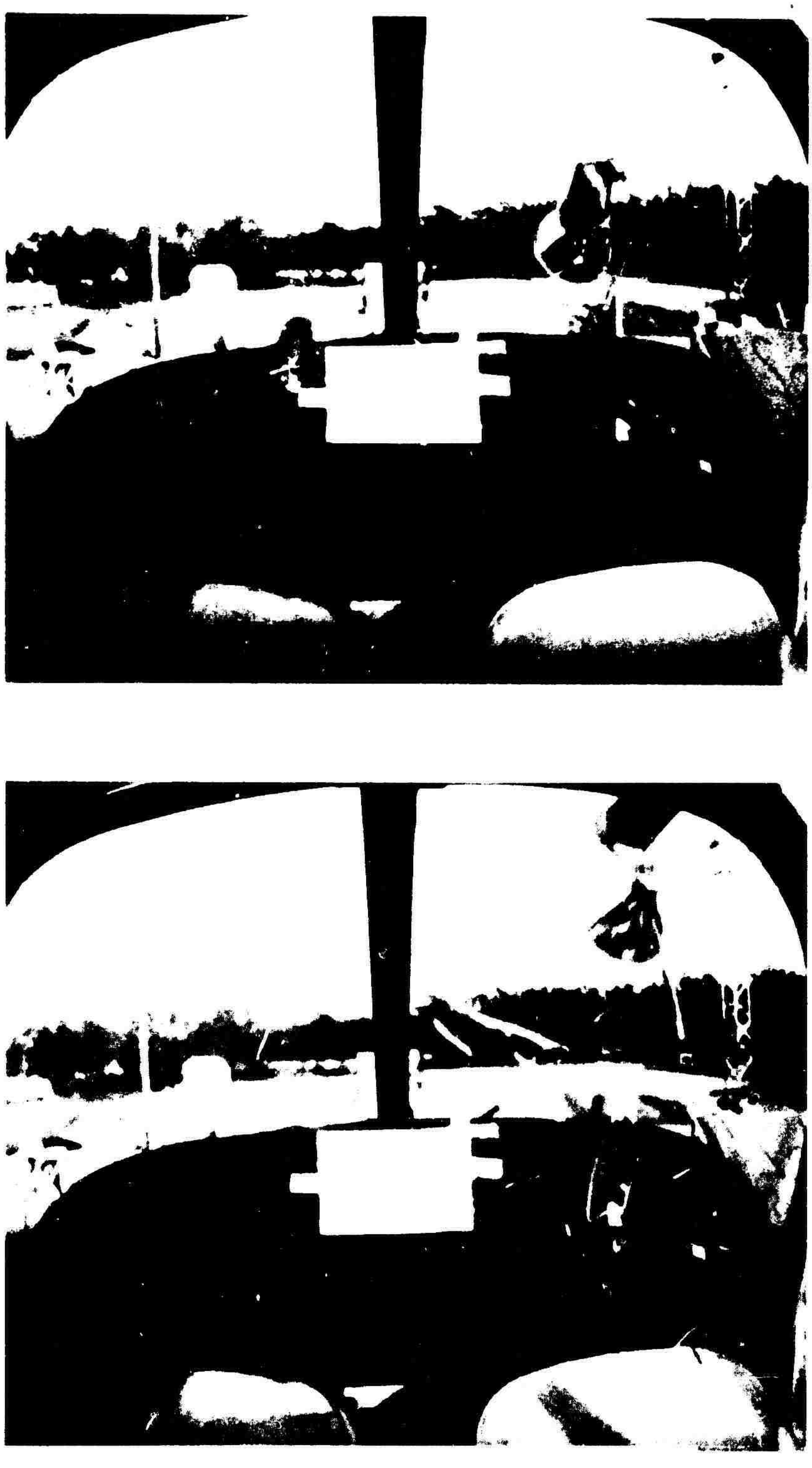

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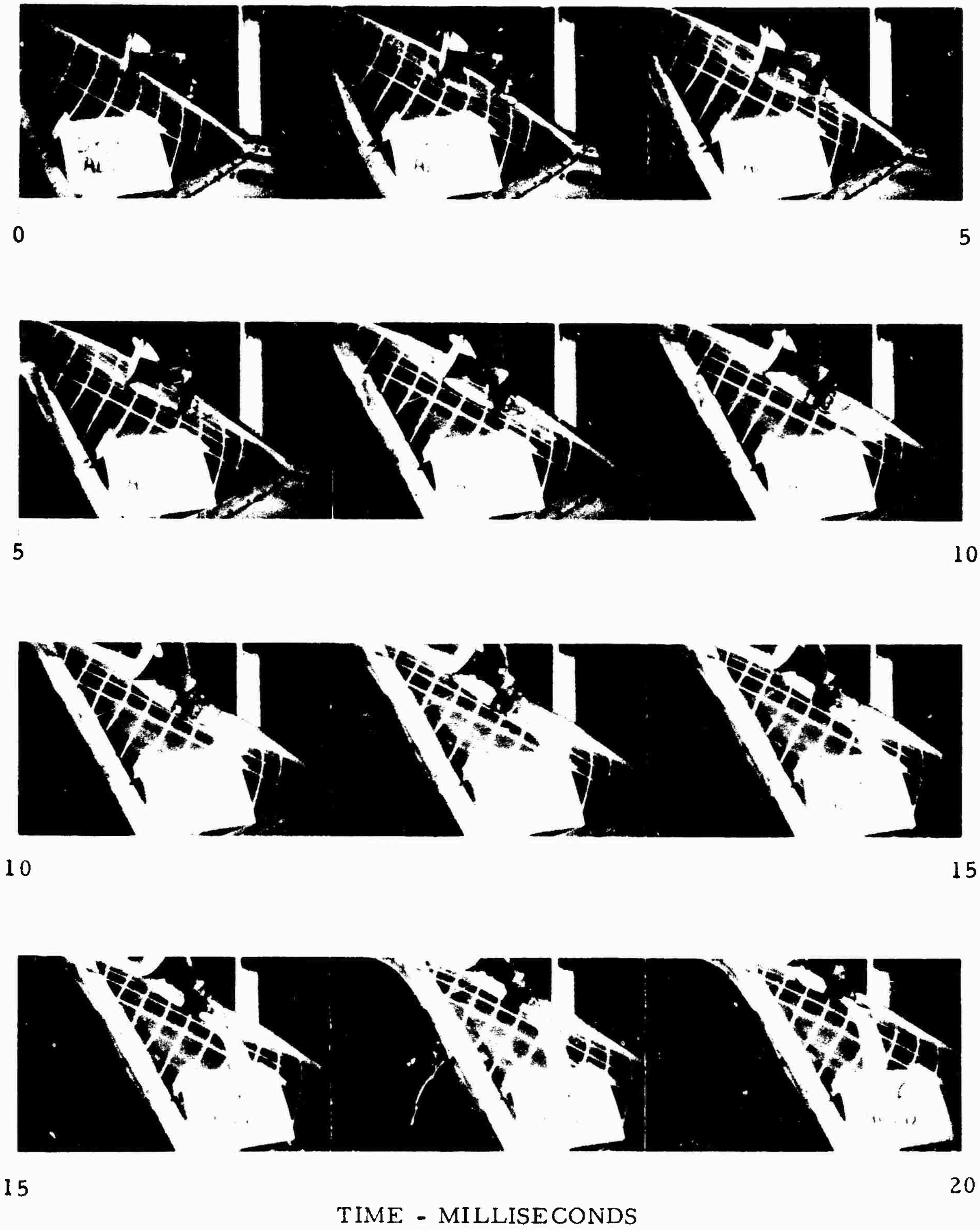
FIGURE 22. TYPICAL PHOTOGRAPHS OF TEST SET NO. 7



75-8-23

FIGURE 23. SEQUENCED PHOTOGRAPHS OF DIMPLING IMPACT

APPENDIX

DATA SUMMARY

Run And Lamp Type	Date Time	Weather & Wind (kn)	Temp	Aircraft Type	W/S Side	Time And Speed	Remarks
ALS-1 PAR-56 Lamp	7-19-74 1330	Clear Calm	88°	Cherokee P28-180	L.H.	5,000 ms 20.0 mi/h	Broke tape only. Lamp shattered when it hit the ground. Lamp tumbled up the w/s.
ALS-2 PAR-56 Lamp	7-19-74 1415	Clear Calm	88°	Cherokee P28-180	L.H.	4,115 ms 24.3 mi/h	Same as above. W/s deflected some.
ALS-3 PAR-56 Lamp	7-19-74 1430	Clear Calm	88°	Cherokee P28-180	L.H.	3,677 ms 27.2 mi/h	No breakage. 1/4" X 4" long mark on w/s, w/s deflected some.
ALS-4 PAR-56 Lamp	7-19-74 1530	Clear Calm	88°	Cherokee P28-180	L.H.	1,744 ms 57.7 mi/h	Shattered w/s and lamp. No deflection of w/s. Pieces of glass 50 feet away.
ALS-5 PAR-56 Lamp	7-25-74 1125	Overcast North 10	78°	Cherokee P28-180	R.H.	2,799 ms 35.7 mi/h	Mud streak up the w/s, 3/4" wide X 6" long.
ALS-6 PAR-56 Lamp	7-25-74 1320	Overcast North 5	78°	Cherokee P28-180	R.H.	2,469 ms 40.5 mi/h	Same as above.
ALS-7 PAR-56 Lamp	7-25-74 1353	Overcast East 5	78°	Cherokee P28-180	R.H.	2,141 ms 46.7 mi/h	Shattered windshield and lamp. Pieces of glass in cockpit and at least 50 feet away.
ALS-8 PAR-56 Lamp and Holder	7-29-74 1110	Overcast SE-3	79°	Cherokee P28-180	R.H.	5,139 ms 19.5 mi/h	No breakage. 4" long mark on w/s.
ALS-9 PAR-56 Lamp and Holder	7-29-74 1130	Overcast Calm	79°	Cherokee P28-180	R.H.	4,186 ms 23.9 mi/h	Broke w/s. Lamp broke when it hit the ground.
ALS-10 PAR-38 Lamp and Holder	7-29-74 1425	Clear East 5	82°	Cherokee P28-180	L.H.	3,259 ms 30.7 mi/h	Scratch on w/s 4" long. Lamp broke when it hit the ground.

NOTE: W/S = Windshield ms = Milliseconds
L.H. = Left Hand R.H. = Right Hand

Run And Lamp Type	Date Time	Weather & Wind (kn)	Temp	Aircraft Type	W/S Side	Time And Speed	Remarks
ALS-11 PAR-38 Lamp and Holder	7-29-74 1510	Clear SE-10	82°	Cherokee P28-180	L.H.	2,450 ms 40.8 mi/h	Two scratched on w/s 4" long X 1/4" wide. Lamp broke when it hit the ground. Holder OK.
ALS-12 PAR-38 Lamp and Holder	7-29-74 1540	Clear SE-10	82°	Cherokee P28-180	L.H.	1,988 ms 50.3 mi/h	Broke w/s and Lamp. W/s broke first.
ALS-13 PAR-38 Lamp	9-9-74 1120	Clear South 5	75°	Cherokee P28-180	L.H.	2,230 ms 44.8 mi/h	No breakage. Mark on w/s. New w/s from factory.
ALS-14 PAR-38 Lamp	9-9-74 1318	Clear East 5	76°	Cherokee P28.180	L.H.	1,974 ms 50.6 mi/h	Broke w/s and cracked lamp.
ALS-15 PAR-38 Lamp and Holder	9-9-74 1454	Clear East 5	77°	Cherokee P28-180	L.H.	2,125 ms 47.0 mi/h	No breakage except the porcelain holder inside the holder frame. Mark on w/s.
ALS-16 PAR-38 Lamp and Holder	9-9-74 1430	Clear East 5	77°	Cherokee P28-180	L.H.	1,977 ms 50.6 mi/h	Broke w/s. Broke little pieces off lamp. Did not break holder.
ALS-17 PAR-38 Lamp and Holder	9-9-74 1500	Clear East 5	77°	Cherokee P28-180	L.H.	1,952 ms 51.2 mi/h	Broke w/s. Broke lamp. Broke porcelain inside of holder. Lamp went through w/s. Holder fell outside of fuselage.
PAR-38 Lamp and Holder and Accel-erometer	9-16-74 1110	Clear Calm	76°	Cherokee P28-180	R.H.	5,208 ms 19.2 mi/h	No damage. Calibration run for acceler-ometer reading of about 25 g.
ALS-18 PAR-38 Lamp and Holder and Accel-erometer	9-16-74 1345	Clear Calm	76°	Cherokee P28-180	R.H.	2,454 ms 40.7 mi/h	Mark on w/s. No accelerometer reading, due to oscillograph not operating.

Run And Lamp Type	Date Time	Weather & Wind (kn)	Temp	Aircraft Type	W/S Side	Time And Speed	Remarks
ALS-19 PAR-38 Lamp and Holder and Accelerometer	9-16-74 1410	Clear Calm	70°	Cherokee P28-180	R.H.	2,449 ms 40.8 mi/h	Mark on w/s. No breakage. Accelerometer reading about 108 g.
ALS-20 PAR-39 Lamp and Holder and Accelerometer	9-16-74 1446	Clear Calm	77°	Cherokee P28-180	R.H.	1,979 ms 50.5 mi/h	Broke w/s and lamp. Accelerometer reading about 156 g.
ALS-21 PAR-38 Lamp and Holder and Accelerometer	9-16-74 1520	Clear Calm	77°	Cherokee P28-180	R.H.	2,120 ms 47.1 mi/h	Broke w/s and lamp. Holder OK. Accelerometer reading about 168 g.
ALS-22 PAR-38 Lamp and Holder	10-10-74 1315	Clear West 8	69°	Cessna 172		3,123 ms 32.0 mi/h	6" mark on w/s. No breakage.
ALS-23 PAR-38 Lamp and Holder	10-10-74 1335	Clear West 8	70°	Cessna 172		2,384 ms 41.9 mi/h	Broke w/s. Broke metal and ceramic of lamp. Holder OK. Lamp and holder found inside fuselage.
ALS-24 PAR-38 Lamp and Holder	10-10-74 1415	Clear Calm	70°	Cessna 172		2,790 ms 35.8 mi/h	Broke w/s. Broke lamp. Lamp and holder went through into fuselage.
ALS-25 PAR-38 Lamp and Holder	10-10-74 1440	Clear Calm	67°	Cessna 172		3,008 ms 33.2 mi/h	Broke w/s. Same as above.
ALS-26 PAR-56 Lamp	11-5-74 1054	Ovrcst West 10	70°	Cessna 172		5,685 ms 17.6 mi/h	No breakage.

Run And Lamp Type	Date Time	Weather & Wind(kn)	Temp	Aircraft Type	W/S Side	Time And Speed	Remarks
ALS-27 PAR-56 Lamp	11-5-74 1110	Ovrcst West 5 Light Sprinkle	70°	Cessna 172		3,404 ms 29.3 mi/h	No breakage.
ALS-28 PAR-56 Lamp	11-6-74 1000	Clear NNW-15 Gusty	58°	Cessna 172		3,317 ms 30.1 mi/h	No breakage.
ALS-29 PAR-56 Lamp	11-6-74 1017	Clear NNW 15 Gusty	58°	Cessna 172		3,030 ms 33.0 mi/h	No breakage.
ALS-30 PAR-56 Lamp	11-6=74 1040	Clear NW 14 Gusty	60°	Cessna 172		2,802 ms 35.6 mi/h	No breakage.
ALS-31 PAR-56 Lamp	11-6-74 1100	Clear NW 14 Gusty	60°	Cessna 172		2,500 ms 40.0 mi/h	Broke w/s.
ALS-32 PAR-56 Lamp	11-6-74 1345	Clear NW 6	62°	Cessna 172		2,631 ms 38.0 mi/h	Broke w/s. Lamp bounced off w/s.
ALS-33 PAR-56 Lamp and Holder	11-6-74 1440	Clear NW 8	62°	Cessna 172		5,901 ms 16.9 mi/h	No breakage.
ALS-34 PAR-56 Lamp and Holder	11-6-74 1455	Clear Calm	62°	Cessna 172		5,137 ms 19.4 mi/h	No breakage.
ALS-35 PAR-56 Lamp and Holder	11-6-74 1505	Clear Calm	63°	Cessna 172		4,289 ms 23.3 mi/h	No breakage.

Run And Lamp Type	Date Time	Weather & Wind (kn)	Temp	Aircraft Type	W/S Side	Time And Speed	Remarks
ALS-36 PAR-56 Lamp and Holder	12-4-74 1420	Clear N 25 Gusty	43°	Cessna 172		4,481 ms 22.3 mi/h	No breakage.
ALS-37 PAR-56 Lamp and Holder	12-4-74 1440	Clear N 25	43°	Cessna 172		4,093 ms 24.4 mi/h	Broke w/s. Small hole about 7" in diameter. Lamp and holder bounced off.
ALS-38 PAR-38 Lamp	12-4-74 1520	Clear N 15	42°	Cessna 172		2,482 ms 40.3 mi/h	Broke w/s. Lamp went through w/s. Lamp did not break except for filament.
ALS-39 PAR-38 Lamp and Holder	12-5-74 1010	Clear N 5	37°	Cessna 172		3,427 ms 29.18 mi/h	No breakage. Tock color photographs.
ALS-40 PAR-38 Lamp and Holder	12-5-74 1040	Clear N 5	38°	Cessna 172		2,473 ms 40.44 mi/h	Broke w/s. Lamp went through w/s. Took color photographs.
ALS-41 PAR-38 Lamp and Holder and Accel-erometer	12-5-74 1600	Clear Calm	39°	Cessna 172		3,351 ms 29.84 mi/h	Broke w/s. Bell & Howell Type 4-203-0001 accelerometer S/N 2831. 7-346 galvanom-eter flat to 190 Hz. Calibrated 9-30-74.
ALS-42 PAR-38 Lamp and Holder	12-6-74 1530	Clear SE 5	45°	Cherokee P28-180	R.H.	3,327 ms 30.06 mi/h	No breakage. Lamp hitting flat on w/s.
ALS-43 PAR-38 Lamp and Holder	12-6-74 1550	Clear Calm	45°	Cherokee P28-180	R.H.	2,760 ms 36.23 mi/h	No breakage. Lamp hitting flat on w/s.
ALS-44 PAR-38 Lamp and Holder	12-10-74 1345	Bkn Clds W 25	35°	Cherokee P28-180	R.H.	2,467 ms 40.53 mi/h	No breakage. Lamp hitting flat on w/s. Cold and windy.

Run And Lamp Type	Date Time	Weather & Wind(kn)	Temp	Aircraft Type	W/S Side	Time And Speed	Remarks
ALS-45 PAR-38 Lamp and Holder	12-10-74 1415	Bkn Clds W 16	35°	Cherokee P28-180	R.H.	2,236 ms 44.72 mi/h	No breakage. Lamp hitting flat on w/s. Cold and windy.
ALS-46 PAR-38 Lamp and Holder	12-10-74 1450	Bkn Clds W 16	36°	Cherokee P28-180	R.H.	2,019 ms 49.53 mi/h	No breakage. Lamp hitting flat on w/s. Cold and windy.
ALS-47 PAR-38 Lamp and Holder	12-10-74 1525	Bkn Clds W 16	35°	Cherokee P28-180	R.H.	1,836 ms 54.47 mi/h	No breakage. Lamp hitting flat on w/s. Cold and windy.
ALS-48 PAR-38 Lamp and Holder	12-11-74 1030	Clear W 7	42°	Cherokee P28-180	R.H.	1,646 ms 60.75 mi/h	No breakage of w/s. Metal moulding on top of w/s bent up. Bright and clear day. Lamp hitting flat on w/s.
ALS-49 PAR-38 Lamp and Holder	12-11-74 1120	Clear W 7	45°	Cherokee P28-180	R.H.	1,527 ms 65.49 mi/h	No breakage of w/s. Metal moulding on top of w/s ripped away. Bright and clear day. Lamp hitting flat on w/s.
ALS-50 PAR-38 Lamp and Holder	12-11-74 1338	Clear W 10	49°	Cherokee P28-180	R.H.	1,448 ms 69.06 mi/h	Broke w/s. Smashed lamp and holder. Lamp went through w/s. Holder ended up outside on ground. Lamp hittin flat on w/s. Bright and clear day.
ALS-51 PAR-38 Lamp and Holder	12-11-74 1420	Clear W 8	49°	Cherokee P28-180	R.H.	3,319 ms 30.13 mi/h	No breakage. Sharp points of holder pointed towards w/s. Bright and clear day.
ALS-52 PAR-38 Lamp and Holder	12-11-74 1450	Clear W 5	48°	Cherokee P28-180	R.H.	2,459 ms 40.67 mi/h	Broke w/s. Lamp and holder bounced off. Sharp points of holder pointed towards w/s. Bright and clear day.

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F